88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № .T-1
(спейсфлайт)
По подписке 1989 г.

SOVIET SHUTTLE
MISSION REPORT

Vol.31 No.1

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DISTRIBUTION DETAILS

Spaceflight may be received world-wide by mail through membership of the British Interplanetary Society. Details from the above address. Library subscription details are also available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by Magnum Distribution Ltd., Cloister Court, 22–26 Farringdon Lane, London EC1R 3AU. Tel: 01–253 3135.

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Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published monthly by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L., Ltd., Aylesbury, Buckinghamshire, England.

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Spaceflight

The International Magazine of Space and Astronautics

Vol. 31 No. 1 January 1989

Front Cover: The Space Shuttle Atlantis blasts off on its first military mission STS 51-J, onboard is Manned Space Flight Engineer William Pailes. An article on the US military astronaut programme begins on p.26. *NASA*

SOVIET SHUTTLE

The Soviet space shuttle, Buran (Snowstorm), was successfully launched on November 15. Three hours and 25 minutes later it made a perfect landing on a concrete runway at the Soviet spaceport of Baikonur, just 12km from the launch pad it had started from. *Spaceflight* correspondent *Neville Kidger* reports on what must be the Soviet Union's greatest space achievement since the launch of Yuri Gagarin.

The unmanned flight of Buran was a very impressive display by the Soviet Union, however the initial launch attempt was aborted on October 29, just 51 seconds before the scheduled start.

The reason for that scrub was a delayed separation of an instrumented block of the azimuthal orientation system from the body of Energia. At the time Maj-Gen (Aviation) V. Gudilin, head of the test directorate of the cosmodrome told reporters that the fault had been with "the platform of the facility for emergency evacuation of the cosmonauts, [it] carries an accurate setting of the rocket's gyroscopes." It was because of this that the automatic countdown was terminated and the test flight rescheduled. The separation should have taken 3 seconds but actually took 38. Overcomplicated design of the joint was blamed. Aleksandr Dunayev, head of Glavkosmos, told a news conference on November 10 that preliminary tests of the Energia Buran system would be finalised the next day and a new launch date set.

Dunayev said that the USSR planned to build several Buran-type orbiters and operate them for decades. He stressed that they would be used to carry spacecraft into orbit "only in exceptional cases", citing the cost of operating the system. Their main tasks would be "the operation of space technology; maintenance operations and recovery of worn-out satellites." He said that no more than 2 or 4 flights could be expected annually. Manned flights would follow the unmanned testing.

The Soviets later announced that Buran would be launched at 0300 GMT on November 15.

Snowstorm and Birdie

TASS correspondent Valentin Ovcharov reported that he had visited the huge assembly building at Baikonur where the orbiters are prepared and saw a second orbiter, called Ptichka (Birdie). The orbiter was covered with 38,000 lightweight heat-absorbing ceramic tiles which could resist temperatures of 2000 degrees centigrade.

These tiles, according to another reporter, could be scratched with a fingernail (he was reprimanded for trying).

Buran can put 30 tonnes into orbit and return with 20 tonnes to land at the runway at Baikonur.

The dimensions of Buran were given by Tass, the orbiter has a length of 36 metres and a wing span of 24 metres. Buran features a crew cabin (split level, as evidenced by the location of the crew access arm) with a volume of almost 70 cubic metres. The craft can carry two to four cosmonauts and six passengers, the Soviets said.

The payload bay has the dimensions of 4.7 metres in diameter and length of 18.3 metres. Vladimir Shatalov revealed that the bay has a manipulator for releasing satellites for deploying them. The manipulator is man-operated.

The overall launch and landing mass of the orbiter can reach 105 tonnes and 82 tonnes respectively. Buran can put 30 tonnes into orbit and return with 20 tonnes to land at the runway at Baikonur.

Unlike the US shuttle, Buran does not carry large reusable rocket engines powered by fuel from a tank to which it is strapped. The orbiter is a payload for the 3,500 tonne-thrust Energia carrier rocket.

Energia takes Buran to sub-orbital speed where it separates from the orbiter. The Buran's propulsion system serves as an upper stage and is ignited at an altitude of 160 km to put the spacecraft into Earth orbit. It is activated once more to enter a circular 250 km orbit.

When gliding in the atmosphere the orbiter is controlled by ailerons, the control vane and air brakes, just as an ordinary aircraft. It is a glide approach without the capability of power landing of fly-around. The aerodynamic flight begins at 40 km and Soviets say that the orbiter can conduct a lateral manoeuvre of up to 2,000 km.

The landing tests at Baikonur, conducted by cosmonauts Igor Volk and the late Anatoli Levchenko, did feature "sustained aircraft engines" which enabled the craft to take off like an ordinary aircraft. However, the engines were switched off for the approach and landing phases to simulate an actual return from space. These types of flights helped to develop the fully automated landing system. The first tests of the automated landing came after the pilots had shown that the orbiter could conduct a controlled landing.

Touchdown speed at landing from an orbital mission is about 340 km per hour and the landing run 1,100 to 2,000 metres. A three-canopy "X" shaped parachute system deploys and is jettisoned when the speed of the orbiter is 50 km per hour. The landing strip at Baikonur is 4.5 km long by 84 metres wide.

Control Centre

A "united control centre" has been established for the landing of the

(Top left) Energia's core stage engines ignite, billowing clouds of steam.

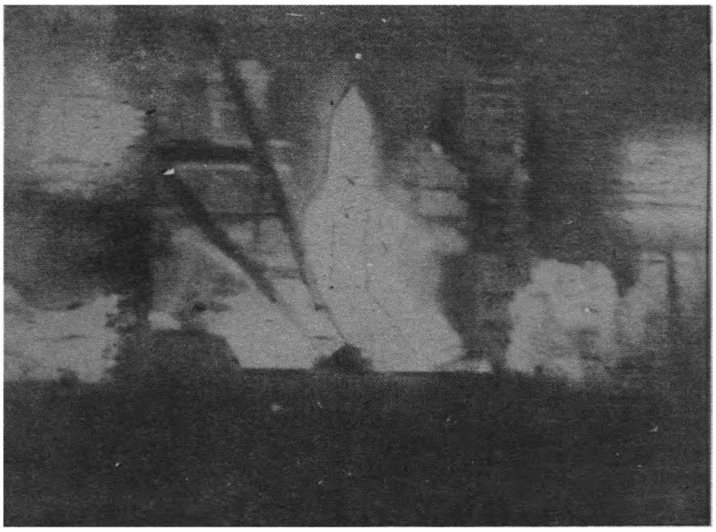
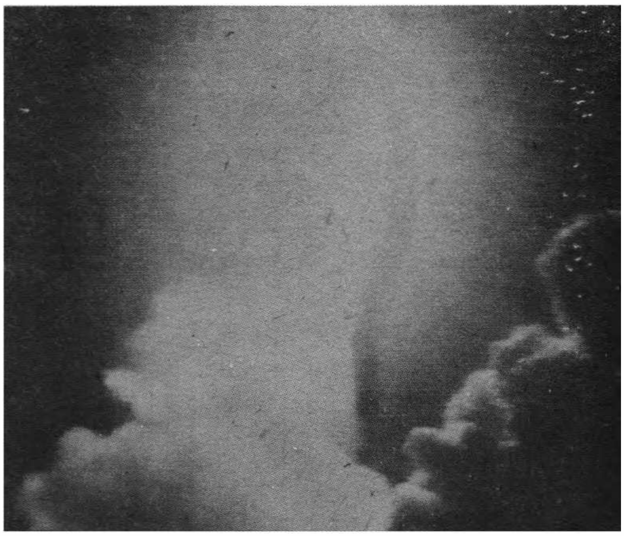
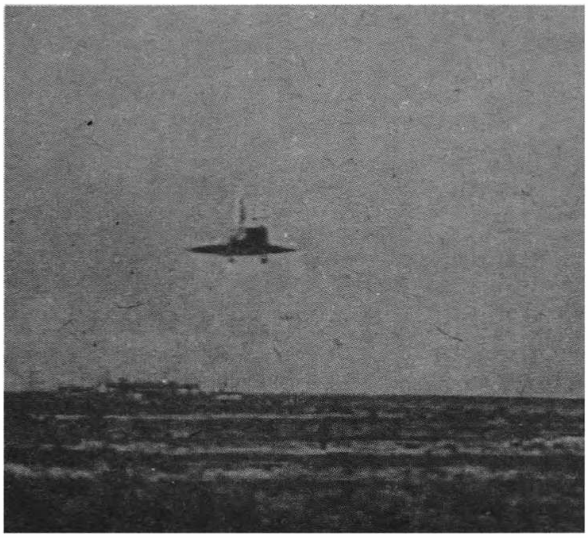
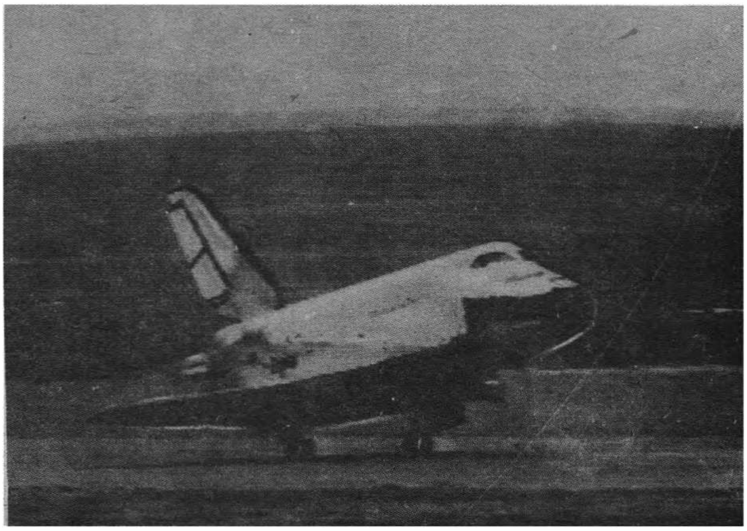
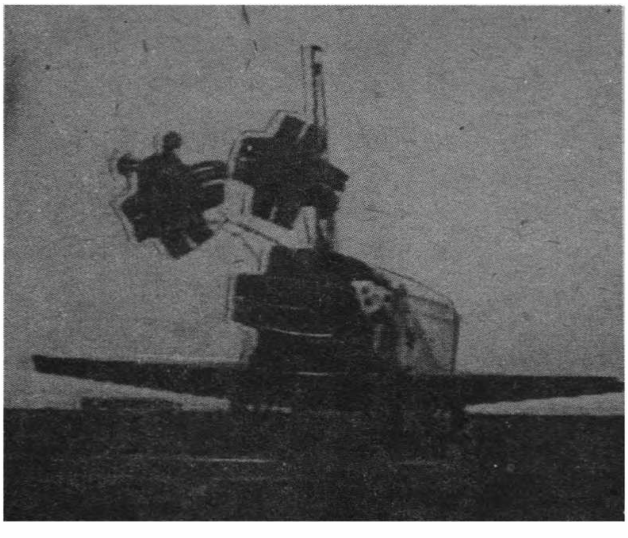
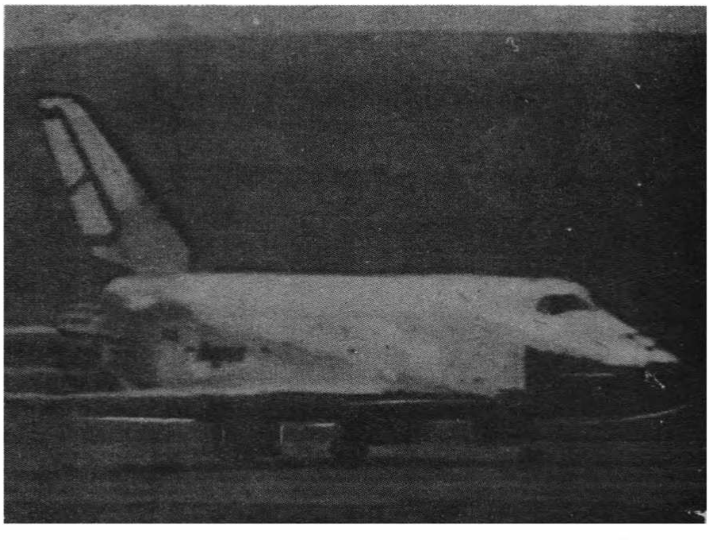
(Top right) Buran and Energia are obscured by the intense exhaust of the strap-on boosters, as the vehicle clears the launch tower.

(Centre left) After completing two orbits of the Earth Buran makes its final approach to the runway at the Baikonur Cosmodrome.

(Centre right) Buran touches down under automatic control.

(Bottom left) Buran is slowed by three parachutes.

(Bottom right) Buran's aft area is discoloured by the firey blast-off and reentry into the Earth's atmosphere.

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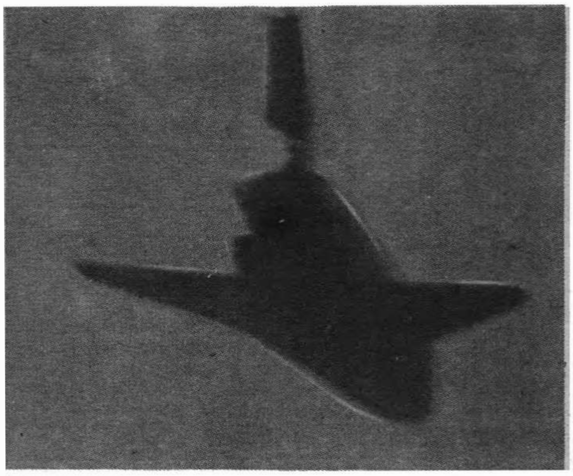
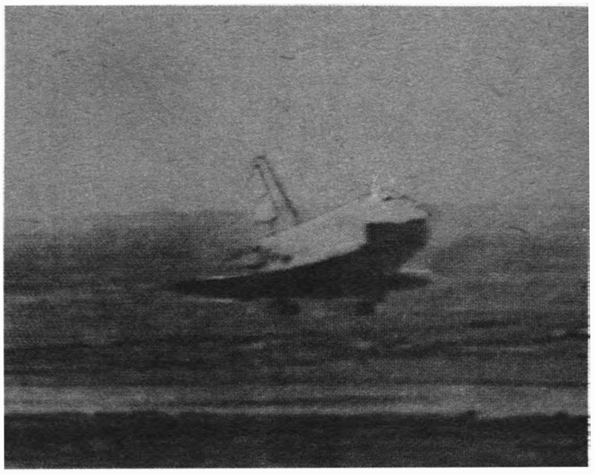


Buran's split rudder air brake is clearly visible in this photograph taken from the Mig-25 chase plane during decent.



Buran seconds before her main gear touch down on the concrete runway at Baikonur.

orbiters, the Soviets said. The landing complex also includes radio aids, ranger finders, landing and air traffic control systems in the area of Baikonur, a six-storey building which contains equipment to receive telemetry and other information, a computer centre, units of navigational and landing systems, and communications and meteorological centres.

The tâsks of the control centre are the detection and guidance of the landing approach and its post-flight maintenance.

Navigators in the main control centre have display units and plan-position indicators which give them information about the orbiter's height, range and speed amongst others.

The Flight of Buran

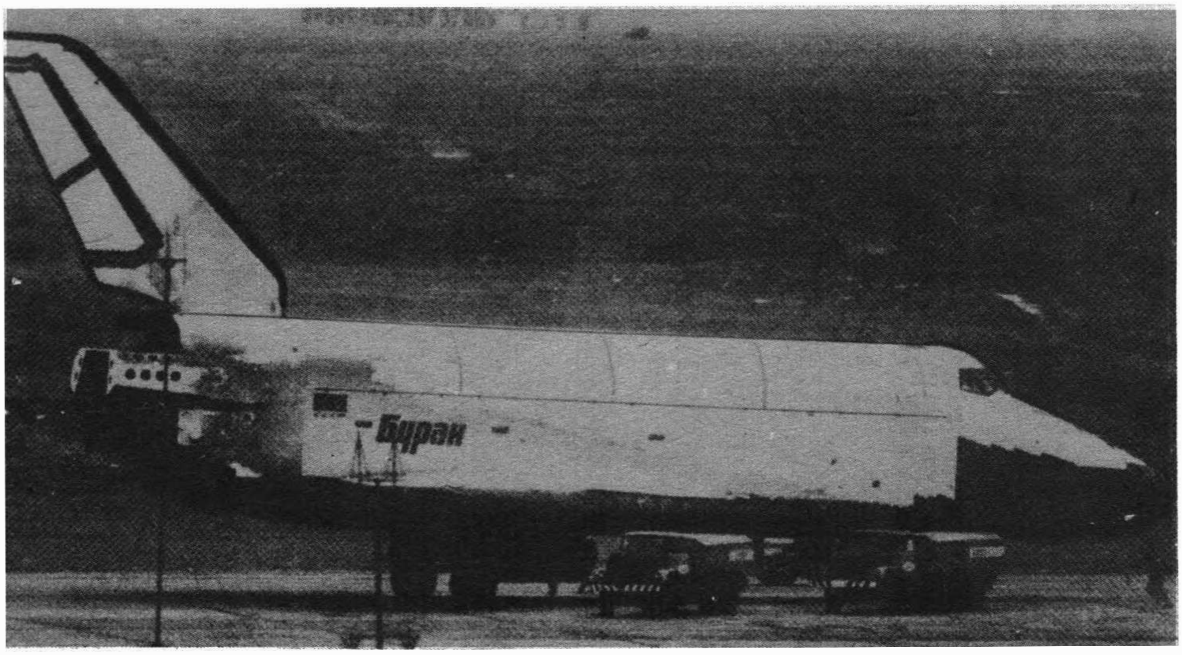
A. Dunayev had promised live coverage of the launch of the Soviet shuttle but in reality both the October 29 attempt and the November 15 launch were not covered in real-time by the Soviet media. Moscow radio announced the event, which occured at 0300 GMT, at 0411 GMT. The landing was reported after only a few minutes delay with the TV of the event being shown less than an hour later.

Pictures of the launch had taken almost 4 hours to be shown on Soviet screens.

The weather for the launch was grey and cloudy. Indeed, the State Commission which authorised the launch met urgently to decide if the conditions were right for the launch to proceed. There was concern because a cyclone was being monitored moving towards Baikonur from the Aral Sea bringing gusting winds. The fear was rain could form ice on Energia and Buran. The temperature at the launch site was just 4 degrees C, and the surface of Energia's fuel tanks would be even colder once loaded with their cryogenic propellants.

Thirty minutes before the launch, Tass said, the launch pad was deserted. During other launches the

Buran is attended to by a number of service vehicles after coming to a stop on the runway. *Novosti*



personnel had been on the launch pad until 15 minutes to ignition, but for Energia the pad was evacuated some six hours before launch when the rocket began to be loaded with liquid hydrogen.

The spacecraft's on-board computer system was activated at 0249 GMT. This put the pre-launch preparations into automated mode. Tass said, "man can no longer interfere". During the final minute the platforms and service towers dislocated from the Energia Buran system. At launch the combined weight was 2,400 tonnes, some 90 per cent of that was fuel.

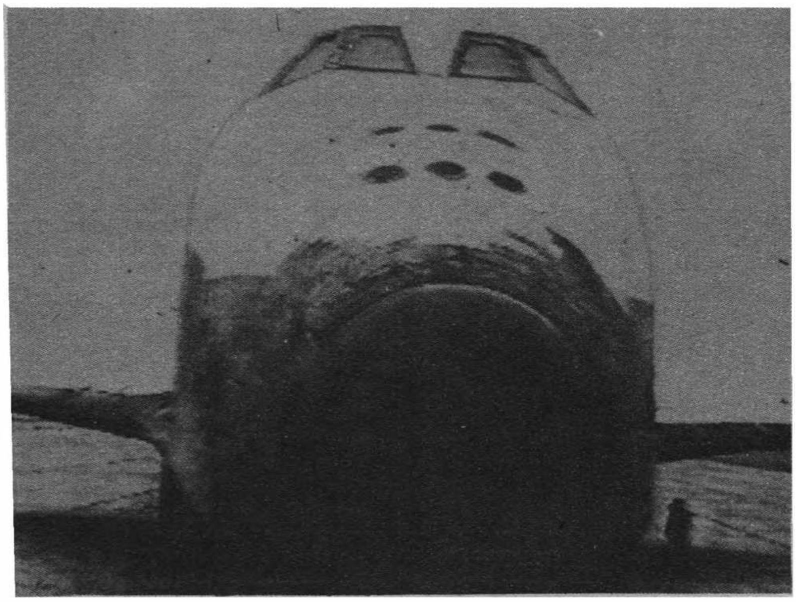
About 8 seconds before launch, according to the TV pictures, the liquid oxygen/hydrogen fuelled core stage, with four single chamber rockets each with a 200-tonnes thrust, ignited. The launch pad was surrounded with a huge cloud of steam as the exhaust was deflected down a 23 metre deep, 20 metre diameter shaft. Then the four strap-ons ignited simultaneously. Each of these liquid-fuelled strap-ons has a four-chamber RD-170 engine with a thrust of 800 tonnes and are powered by liquid oxygen and kerosene.

The pad was illuminated by the bright glow as the rocket lifted slowly off the pad and shortly ascended into low grey clouds. Two and a half minutes later the rocket was at an altitude of 60 km. The strap-on first stage rockets, having depleted their fuel, were separated in pairs to land back on Earth. The Soviets did not recover the stages this time, but will do so in future. The rockets can be parachuted to Earth for recovery and reuse.

The core stage continued burning until eight minutes after ignition when, at an altitude of 110 km it separated from the orbiter. This was to ensure that the core stage entered a sub-orbital trajectory that would ensure it was destroyed in the atmosphere over the Pacific Ocean. Buran, however, continued upwards. The orbiter began a "pre-start system for creating artificial gravity to separate the fuel and gas," Soviet TV reported.

The orbiter's own manoeuvring system fired for 67 seconds once an altitude of 160 km was reached. At 0347 GMT, after another 42 second burn, Buran reached the calculated 250 km orbit at an inclination of 51.6 degrees. It then flew over the Pacific Ocean, to the west of the southern tip of the south American continent. The orbiter was orientated in space with its port wing towards Earth.

During its planned two orbit mission Buran's telemetry was continuously monitored by the Soviets. The flow of data was uninterupted, not "even for a second," they said.



An unusual view of Buran standing on the runway at Baikonur soon after landing.

The communication system for the mission involved the Soviet Earth-based tracking network stretching from the Crimea to the Far East being supplemented by four ships and four satellites.

The research ships Cosomonaut Vladislav Volkov and Cosmonaut Pavel Belyayev were located off the western coast of Africa while the other two – the Cosmonaut Georgi Dobrovolski and Marshel Nedelin – were stationed near the western coast of South America.

Two Molniya satellites in highly-inclined, highly-elliptical orbits and two geostationary satellites – Luch and Gorizont – were also used to relay data.

The transmitted data was displayed in real time to the staff of the Moscow control centre.

The Soviets did not release any pictures from the shuttle in orbit. Although pictures of the rotating Earth were visible on screens at the Flight Control Centre, presumably transmitted from cameras onboard Buran.

After turning around with its nose now pitched up, the orbiter entered the Earth's atmosphere.

Western analysts said that the orbiter demonstrated an "extensive cross-range capability" on this portion of the flight with the spacecraft initiating a long banking manoeuvre to the right to put it on target for the Baikonur cosmodrome. Other banking manoeuvres were used to slow the spacecraft down from 25 times the speed of sound to landing speed.

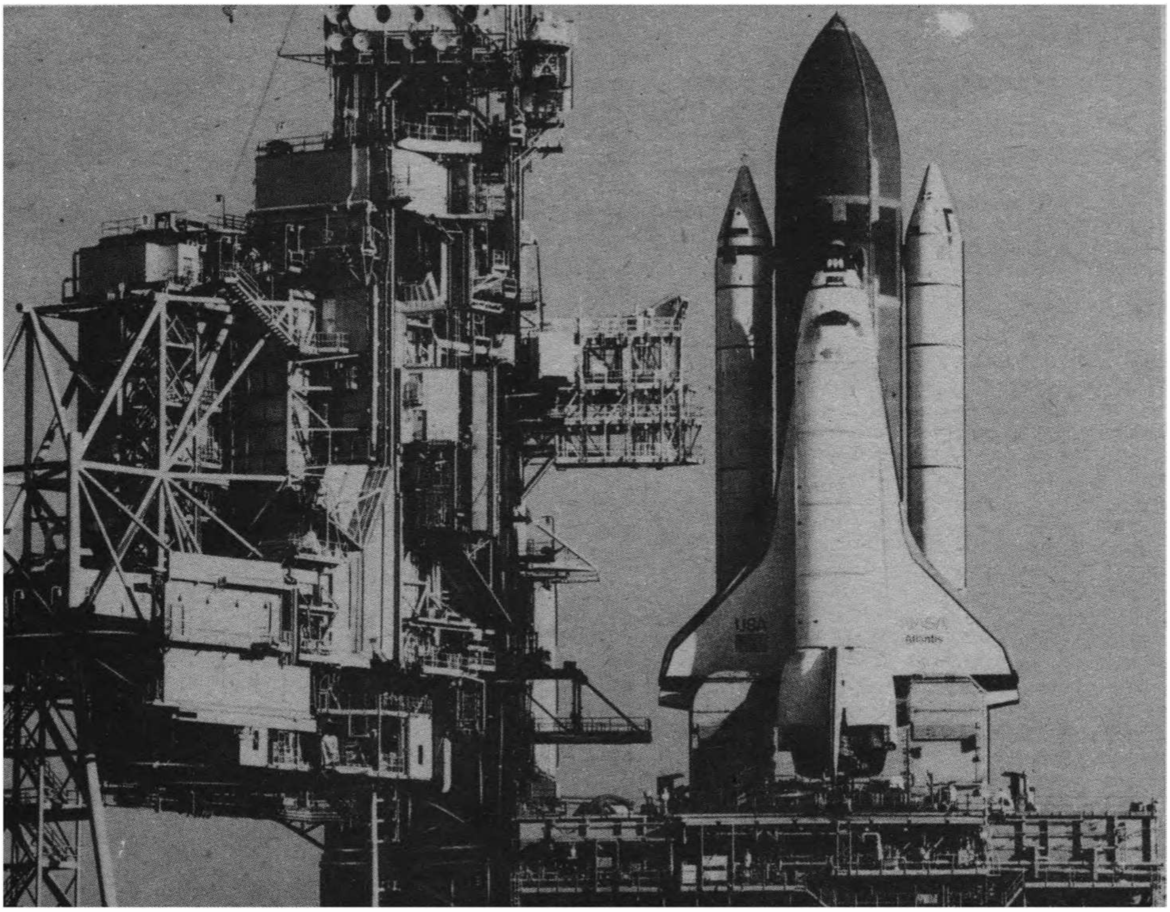
With the orbiter closing on Baikonur it completed a tight turn to put itself onto the proper heading for the approach and landing. Many features of the deorbit and landing were similar to those used by the US shuttle.

A Mig-25 fighter aircraft, piloted by a man who may be a trainee shuttle pilot, intercepted the descending orbiter and beamed TV pictures of the final approach to the concrete runway. Buran deployed its landing gear and, slightly unevenly, touched down at 0625 GMT. It rolled to a stop after about 30 seconds after discarding the three parachutes which had deployed after touchdown. The first mission of Buran had ended in complete triumph with the white-and-black vehicle looking slightly scorched and worn in certain areas.

Soviet leader Mikhail Gorbachev, whose policy of openness had allowed the Soviet people and the world to share the flight of Buran, said that the flight represented an "outstanding victory" which opened up a "qualitatively new stage in Soviet space research."

However, Mr Roald Sagdeyev described Buran and its American counterpart as costly mistakes. Sagdeyev, the retiring Director of the Soviet Space Research Institute, said the shuttle "is technology of the 21st century, why should we pay 20th century money for it?"

Soviet reports said that the next flight would be manned and that a docking with the Mir station was anticipated. The manned flight's date was not known, however, because the first flight's results would need to be analysed thoroughly.



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Atlantis in Action

The space shuttle Atlantis blasted off into almost complete secrecy on mission STS-27, the second shuttle flight following the Challenger accident. This was the third dedicated military shuttle mission and the second for Atlantis.

Atlantis was launched at 14:30 GMT on December 2, the final launch time was revealed just nine minutes before T-O. On November 28, shortly after midnight, NASA set an invisible countdown clock in motion. The launch had originally been scheduled for December 1, but the threat of showers and unacceptable high altitude winds caused a postponement of 24 hours. High winds also threatened to halt the second attempt but the winds died down and Atlantis lifted off into near perfect skies. The good weather conditions resulted in some of the best television pictures of a shuttle launch, with the Solid Rocket Booster (SRB) separation clearly visible.

Top: Atlantis on the launch pad prior to launch on December 2, 1988 on Mission STS-27.

Bottom: The five-member crew for Mission STS-27, dressed in their partially pressurized flight suits, walkout of the Operations and Checkout Building on their way to Pad 39-B. From right to left are: Commander Robert L. "Hoot" Gibson; Pilot Guy S. Gardner; and Mission Specialists William M. Shepherd, Richard M. (Mike) Mullane and Jerry L. Ross.

During the launch a NASA Public Affairs Officer provided commentary, but the usual communications between the crew and mission control were not broadcast. Soon after launch mission control made the following announcement:

> "This is Mission Control Houston at 4 hours 3 minutes 45 seconds mission elapsed time for the flight of STS-27. The crew of Atlantis has been given a go for orbit operations by the Mission Control Center. The Atlantic crew members are doing well, and all systems of the orbiter are performing satisfactorily."

This was the last status report from Mission Control until the re-entry and landing.

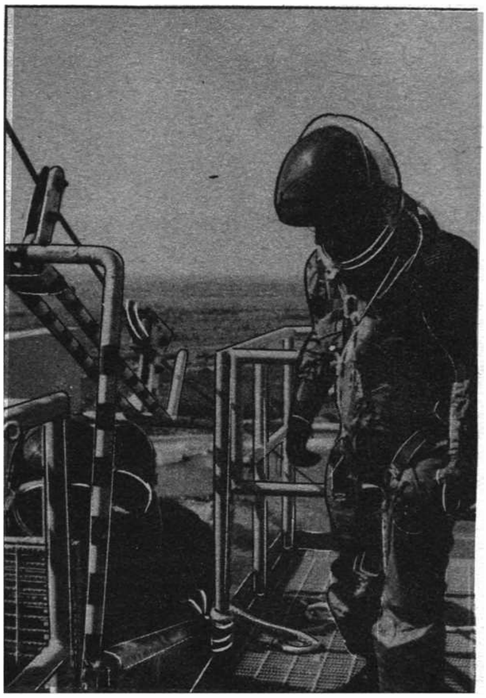
Despite various attempts by NASA and the Department of Defense the details of previous military missions were leaked to the press well in advance. STS-27 was no exception. Even the Soviet news agency Tass described the top secret payload:

> "The main task of the secret mission is to put into near-Earth orbit a new generation reconnaissance satellite, code-named Lacrosse. The satellite will conduct surveillance of the territory of the Soviet Union with the help of updated radar. The Pentagon plans to deploy in the next few years four other similar satellites which will play the role of an 'eye' for the new strategic bomber B2 known as "Stealth."

Atlantis was launched into a high inclination orbit to allow Lacrosse 80% coverage of the Soviet Union. The $500 million satellite was thought to have been deployed by the shuttle's remote manipulator the day after launch. Lacrosse's onboard systems were checked out while Atlantis stood by; if any malfunctions were discovered the expensive satellite could have been retrieved by the shuttle crew.

Atlantis returned to Earth and made a landing at Edwards Air Force Base on December 6.

The SRBs for STS-27 were returned to Cape Canaveral Air Force Station in the evening of December 3. Initial examinations of the booster exteriors revealed no damage to the joints that caused the Challenger accident.



STS-27 crew members rehearse getting into a slide wire basket on the 195 foot level of Pad 39-B during a countdown dress rehearsal for the astronauts and the KSC launch team prior to the launch of Atlantis. *NASA*

Freedom Docking Tests

Preliminary tests on a docking mechanism designed for use on the Space Shuttle orbiter and Space Station Freedom have been successfully completed. The tests were carried out by NASA, McDonnell Douglas and United Technologies.

The mechanism is designed to complete a docking manoeuvre in space between the orbiter and the station. It accommodates the capture of two free flying bodies while dissipating the energy from impact. Subsequent to capture, the mechanism also aligns the two space vehicles and provides a pressurised passageway.

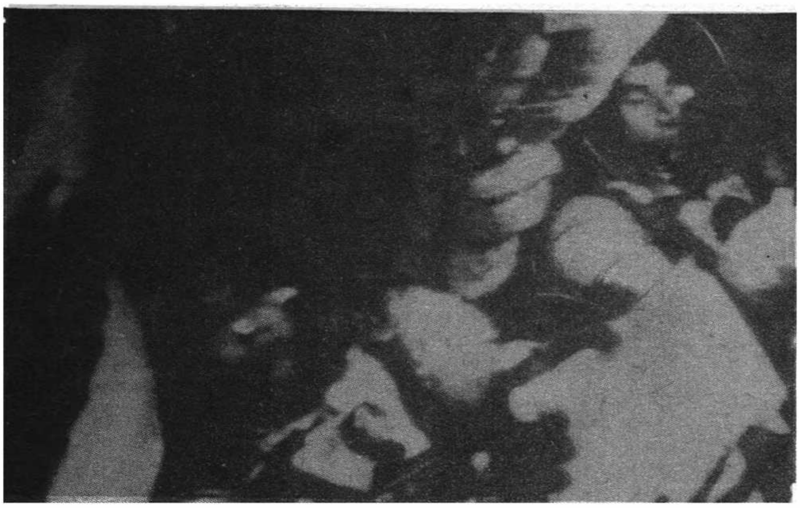
The dynamic testing was performed at NASA's Marshall Space Flight Center in Huntsville, Alabama, and actually achieved simulation of docking the orbiter to Space Station Freedom.

The mechanism achieves capture and energy absorption using computer controlled electro-mechanical actuators/attenuators. This is the first US space docking mechanism development since the Apollo–Soyuz docking system in the mid-1970's and is more complex because of the unique geometry of the shuttle orbiter.

The docking mechanism on the orbiter will be located 11.88 m (39 ft) forward of centre of gravity. Consequently, when contact is made with Space Station Freedom, there will be a jack knife effect. Thus, special effort must be applied to absorb that energy, and the computer controlled system is programmed to cause the electro-mechanical actuators/attentuators to respond correctly.

The overall design of the mechanism and the design and construction of the control system electronics was performed by McDonnell Douglas Astronautics Company. The construction of the docking structures was done by United Technologies Space Flight Systems in Huntsville. The work was completed under a NASA Marshall Space Flight Center research and development contract.

INTERNATIONAL SPACE REPORT



A TV picture transmitted from the capsule during lift-off of the Franco-Soviet mission to the Mir space station. The launch took place at 18:50 Moscow time on November 26, 1988 and the Soyuz TM-7 docked with Mir at 20:16 on November 28.

The white marks near the cosmonauts' faces are reflections of a light source in their space suit visors.

On board Soyuz TM-7 were Soviets, Alexander Volkov, Sergei Krikalev and French cosmonaut Jean-Loup Chretien.

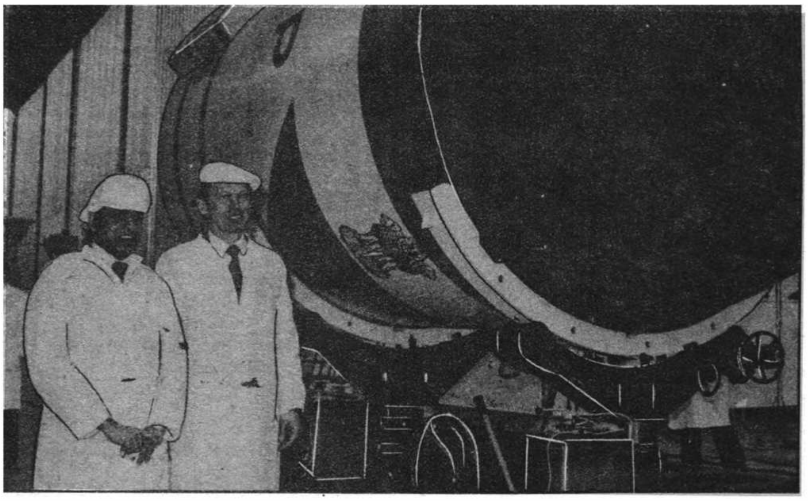
Vladimir Titov and Musa Manarov were due to return to Earth on December 21, 1988 after spending a year in orbit. Jean-Loup Chretien will return with them.

Soviet–Indian Cooperation

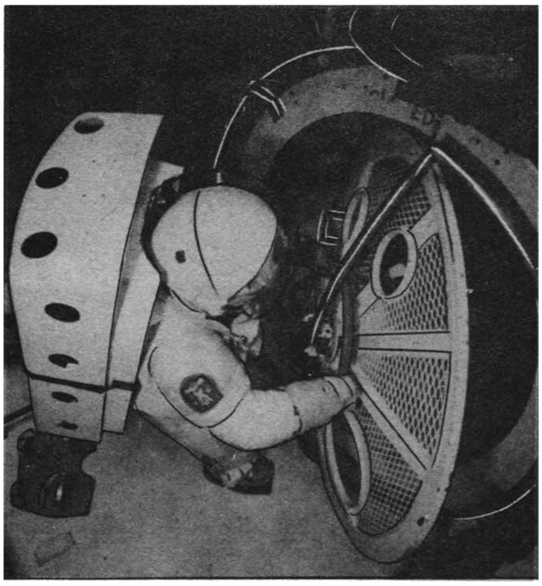
The Soviet Union and India have signed an agreement for the launch of the IRS 1-B satellite by a Soviet launch vehicle.

At a meeting in New Delhi the Soviet and Indian space officials drew up a plan for cooperation in space research for the next ten years. The plan includes an agreement for the launch of the ISR 1-B earth resources satellite in 1991. The Soviet Union launched the satellite's predecessor IRS-1A on March 17, 1988 by a Vostok (A1) vehicle.

Glavkosmos head Aleksandr Dunayev said India has been offered facilities for carrying out experiments onboard Mir and the possibility of launching a dedicated module to be docked to Mir was discussed. Dunayev said Soviet officials will meet again with their Indian colleagues to discuss the technical problems involved.



Dr. K. Kasturirangan, Project Director, IRS and Dr. I.V. Goreshkov, Project Director on the Soviet side stand by the launcher shroud of the IRS-1A operational remote sensing satellite launched on March 17,1988. *ISRO*



An airlock concept for the Freedom space station is evaluated by astronaut Gregory Harbaugh in the weightless environment of a 25-feet deep pool at the Johnson Space Center. The hatch seals with the assistance of pressure which may be applied in either direction. *NASA*

Astronaut Bobko Retires

Astronaut Karol Bobko (Col. USAF) retired from NASA and the US Air Force on January 1, 1989. Bobko has commanded three shuttle flights.

Bobko has been an astronaut since 1970 and was a member of the Skylab medical experiments altitude test in 1972. He served on the astronaut support crews for the Apollo–Soyuz Test Project in 1975 and the Shuttle Approach and Landing Tests at Edwards Air Force Base.

Bobko, a member of the British Interplanetary Society, flew three Shuttle missions, they were, STS-6 (the maiden flight of Challenger), STS 51-D and STS 51-J (a DoD mission and the first flight of Alantis).

Bobko will be joining the Space Systems Division of Booz, Allen and Hamilton, Inc. He will be directing their activities in the Houston area with initial emphasis on Space Station programme support.

Roelof Shuiling

Magellan Fire Report

The Magellan probe to Venus suffered a small but intense electrical fire on October 15, 1988. At the time Magellan was in the Spacecraft Assembly and Encapsulation Facility (SAEF-2) at the Kennedy Space Centre (KSC).

The Magellan was in the process of undergoing an extensive checkout of the electrical power system following the connection of a power control unit. A pair of test batteries had been installed in the spacecraft to support this activity. During this procedure sparks, flames and smoke were observed from the battery connector and fire fighting measures were initiated. A halon fire extinguisher was directed at the battery connector and its thermal blanket. The flames momentarily subsided and then rose again from beneath the battery thermal blanket. Technicians cut away portions of the blanket, sprayed the area again with the fire extinguisher and the flames died. Although some minor sparking was observed there was no further indication of fire or smoke.

An investigation board was formed to determine the cause of the fire, analyse the damage, and how to prevent such occurences in the future. The board was formed under the chairmanship of Jon B. Busse, Director of Engineering at NASA's Goddard Space Flight Center. Additional board members included: Chester Vaughn, Chief of the Propulsion and Power Division of the Johnson Space Center (GSFC); William G. Mahoney, Chief of the Payload Processing Division of KSC; Brian Keegan, Deputy Director of the Office of Flight Assurance at GSFC; and G. Ernest Rodriquez of GSFC.

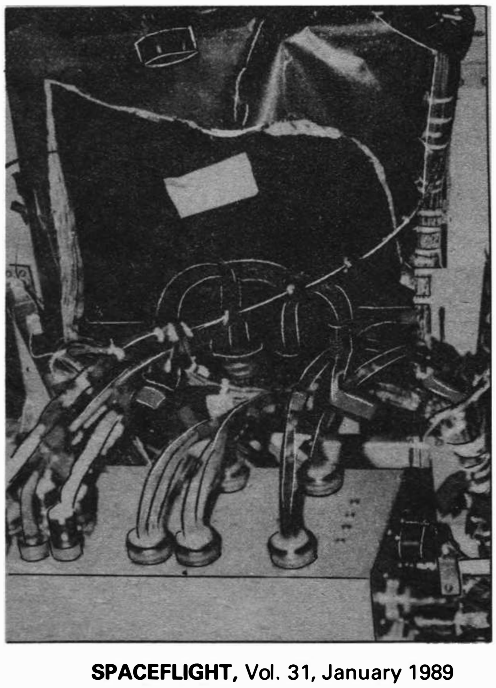
On November 9, the board released their findings. The primary cause of the fire was the incorrect connection of a jack. This created a short circuit within the connector that resulted in electrical arcs which created additional short circuits. This in turn caused damage to the battery connector and thermal blanket.

Contributing causes were that, although the jack was designed to prevent incorrect connections, it was possible to get electrical contact on several of the 37 pins in the jack. In addition the technician had to make the connection in a confined area without direct visibility of the jack.

The damage to Magellan was determined to be confined to the test battery, a connector, and a thermal insulation blanket. The total hardware cost is estimated at approximately $87,000. There remains no impact to the Magellan launch date as a result of the incident.

Roelof Schuiling

Part of the Magellan spacecraft in which an electrical fire damaged a test battery while undergoing installation. *NASA*



The insignia for mission STS-28. Designed by the astronaut crew, it depicts America (the eagle) guiding the American space program (the Space Shuttle) safely home from an orbital mission. *NASA*

Cassini Gets ESA Go Ahead

ESA's Science Programme Committee (SPC), at its meeting in Paris on November 24-25, selected the planetary Cassini/Titan probe mission as the Agency's next scientific project.

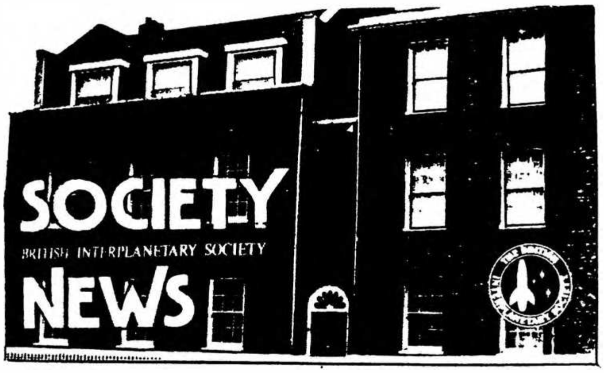
The Cassini mission was named after the French-Italian astronomer who, in the 17th century, discovered several of Saturn's moons and ring features, the so-called Cassini division. The project is a cooperative international mission involving NASA and ESA. The Saturn moon Titan, which is the largest moon in the solar system, is a special target for the Cassini mission. This intriguing body is also the only moon in the Solar System which is known to have a thick, organic-rich nitrogen atmosphere. The surface pressure is 1.5 bar and the temperature is 94K (−179°C). Scientists believe that the chemical processes in the Titan atmosphere may resemble those at work on the primitive Earth before the origin of life.

The SPC decision is the conclusion of a six-year study, which started in early 1983 after the initial proposal was received from a European team led by Dr. Daniel Gautier from the Observatoire de Paris, Meudon, France, and Dr. Wing Ipp of the Max-Planck-Instut für Aeronomie, Katlenburg-Lindau, Germany (FRG) who suggested that this mission be undertaken jointly with NASA.

"With Cassini, and after the remarkably successful Giotto probe mission, ESA is introducing planetary exploration as a major theme in Europe's Long term Space Science Programme, Horizon 2000" said Roger Bonnet, Director of ESA's Scientific Programme.

Saturn and its system of rings and satellites, in particular Titan, were briefly encountered in 1980-81 by the Voyager 1 and 2 spacecraft. The Cassini mission will place a NASA-built orbiter around Saturn which will target and deliver the ESA-built probe into Titan's atmosphere. Cassini is scheduled to be launced in April 1996 by NASA. It will arrive in the Saturn system in October 2002. En route to Saturn, the spacecraft will fly-by the asteroid 66 Maja in 1997 and Jupiter in late 1999.

The major event, which will take place upon arrival of the Cassini mission to Saturn, is the targeting and release of the ESA-built probe into Titan's atmosphere. The probe was named Huygens, after the Dutch astronomer and physicist (1629-1695) Christian Huygens who discovered Titan and the Saturnian rings in 1656. A large conical decelerator will slow the probe down to reach subsonic speed (266 m/s) at an altitude of 180 km. Then a parachute system will be deployed to allow a slow, two to three hour descent to the surface of Titan which may be covered by ethanemethane lakes or oceans, as many scientists speculate. The 5 m/s low-velocity impact may be soft enough to allow analysis of a surface sample before the probe diets. During the descent of Huygens, the orbiter will be used as a radio relay station to transmit the probe's data to Earth. Subsequently to Huygen's mission, the Cassini orbiter - during its four-year Saturn tour – will fly over Titan's surface more than 30 times, sometimes at an altitude of only 1000 km.



Membership

Our thanks to all members who have responded by completing and returning their forms for renewal of membership for 1989. Subscriptions to the Society for 1989 fall due on 1 January 1989 and it is now an urgent matter for anyone whose dues are outstanding to send to the Society if magazines are to be dispatched to them without interruption.

Many members take the opportunity when sending to the Society at this time of the year to add a few lines of comment about the Society. Replies are, of course, sent when called for, but usually this is not the case and we would like to express our appreciation for all viewpoints received. Lawrence Brown, ACT, Australia writes:

> Please find enclosed my payment for Fellowship of the BIS. My congratulations and thanks for another year of informative and challenging articles in the Society's publications. They form my most regular and in-depth source of news in the field of astronautics. Thank you for all your efforts.

The Society aims to continue to actively promote its objects in the coming year and it is with this in mind that fees for 1989 were determined. The increase in fees for 1989 has prompted very few comments and these have mainly centred on the use of the word 'modest'. Donald Babbage, Essex writes:

> I enclose my subscription for 1989. I think it only right to express my view that a 17½% increase cannot really be described as 'modest'. I thought long and hard before renewing.

Commenting on the increase the Executive Secretary points to the continuing need to counterbalance inflation which adds significantly to the cost of publications and their distribution and, additionally, to the need to ease the Society's tight budgets of recent years and so enable it to continue operating with adequate staff and modern office facilities. With inflation at its present level and possibly going higher, the extra money which the Society is asking of its members is, in real terms, a fractionally small amount that is considered essential to the Society's future operations. Seen in this light, the increase merits enthusiastic support and members who have not yet renewed for 1989 are urged to do so without delay.

Members Write:

I am delighted to enclose my re-subscription to ***Spaceflight.*** I am proud to be part of an organisation which helps to improve the quality of life on Earth for all Mankind by supporting the worldwide trend to explore and exploit the limitless environment of Space.

Enclosed is a cheque for a copy of the March 1988 issue of ***JBIS (Journal of the British Interplanetary Society).*** I wish that I had learnt about the British Interplanetary Society many years ago! I consider it an honour to be a Member now.

* * *

Eugene Popin – Obituary

We much regret to record the death of the Society's oldest Fellow, Dr. Eugene Popin, just a few months short of his 101st birthday.

Dr. Popin played a major role in the definition and development of many aspects of space law. His remarkable life included membership of the Central Drafting Committee of the Peace Conference from 1918 to 1920, an active role in the formulation of the Paris Convention on Civil Aviation in 1919 and Director of the Institute of Air and Space Law at McGill University. He was a founder and elected first President of the International Institute of Space Law in 1951 and authored numerous pioneering works on air and space law.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Subject to space being available members may also apply for a ticket for one guest.

LIBRARY

The Society Library is closed until further notice due to continuing building work at the Society's HQ.

4 January 1989, 7.00-8.30 p.m. Lecture

ROCKET MAIL

A lecture by James Goddard, Curator of Space Technology of the Science Museum. Three decades before satellite communications became a reality, rocket technology promised another means of communication over substantial distances. Before the 1930's, 'Rocket Mail' would, it was argued, result in publicity and funds for contemporary rocket pioneers. Was it ever a pragmatic approach to communications or, as some suggest, merely a fund-raising exercise resulting in a colourful and lucrative market for the philatelist?

Admission is by ticket only. Members should apply in good time by enclosing a stamped addressed envelope.

1 February 1989, 7.00-8.30 p.m. Lecture

THE DAWN OF THE SPACE AGE

A lecture by Dr. John Becklake. The space age began on October 4 with the launch of Sputnik 1. This was the culmination of a sequence of events dating from the start of the 20th Century. The development of rocket technology between 1900 and 1957 and the change on the political and public awareness of the imminence of space flight during this period will be discussed with the aid of slides and unique film clips.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

March 1 1989, 7.00-8.30 p.m. Lecture

SOME INTERESTING SPACE PIONEERS

This lecture by Professor Ian Smith reviews the contribution made by number of noted space pioneers known to the speaker, including Wernher von Braun and Val Cleaver.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Delegates at the opening ceremony of the IAF Congress, Bangalore, India, October 1988.

Society at 39th IAF Congress Bangalore

The Bangalore Congress, held during the period 10th to 14th October 1988, attracted an attendance of 875 from 33 countries. The strong UK contingent included four Members of the Council and the Executive Secretary.

The Society's official delegates were Dr L. R. Shepherd (Vice-President) and the Executive Secretary.

The Opening Session began with a message from the Prime Minister, Mr Rajiv Ghandi, calling for a concerted effort to enable developing countries to have full access to the benefits of space technology. Mr Ghandi had intended to inaugurate the Congress personally but was prevented from doing so by other circumstances. His speech was read by the Union Minister of State and Technology, Mr K. Naryanan.

Mr Ghandi said that India had made important strides in its own space progamme, which was closely linked to its developmental needs. Space technology touched communication, meteorology, agriculture, education, environment, health, entertainment and disaster mitigation. It had the potential to provide a new perspective of the Earth.

The Indian Space Programme began 25 years ago with the establishment of a sounding rocket station at Thumba. India had launched 11 application satellites over the last two decades, eight of which they had built themselves. Today, the multi-purpose Insat satellites have revolutionised communications in India, enabling those in even the remotest parts to be in touch with the mainstream of the Nation, while remote sensing applications were providing vital inputs in the management of agricultural, mineral, environmental, forest and soil resources.

The President of the IAF, Dr J. Ortner, pointed out that the IAF now has more than a hundred members from 38 nations though the member-bodies belong to only one quarter of the nations of the world. He confirmed that an important goal of the IAF was to motivate all nations to work together in peace for the benefit of mankind. The fact that the Congress was being held in India showed the IAF emphasis on the developmental perspectives of space technology. The Congress theme was "Space and Humanity", with India an exceptional example of how a developing country could use space, even with limited funds, for the well-being of its people.

Dr V. Kopal read a message from the UN Secretary General, Mr Perez de Cuellar, emphasising that the benefits of space technology should be made available to all countries.

Professor U. R. Rao, Chairman of the Indian Space Research Organisation said that the Indian Space Programme had seen both its successes and failures. What sustained its development was the conviction that its space programme could transform the lives of the people of the country.

More than 600 scientific and technical papers were presented at the 70 sessions, attracting an average attendance of 40 per session. It was reported that 6000 had visited the accompanying Space '88 exhibition.

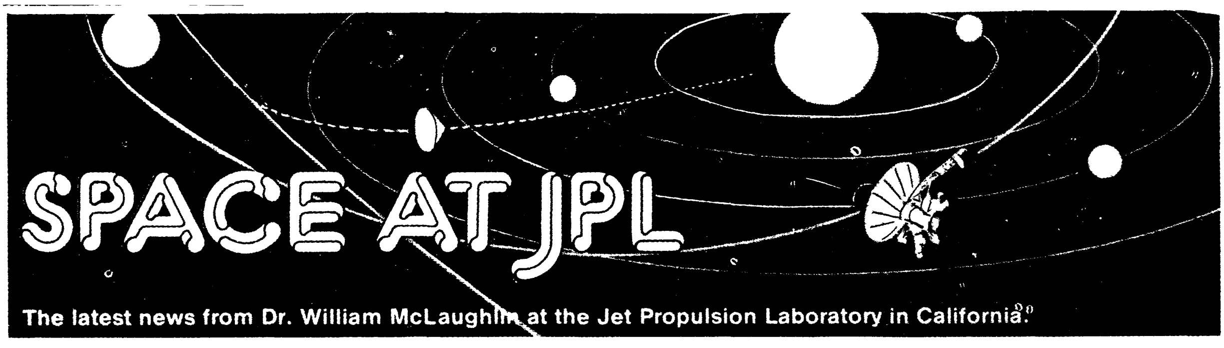
At the business sessions Dr G. Van Reeth was elected President of the IAF for the following year. The six Vice-Presidents also elected were Dr Chernyi, Dr Joachim, Dr Rao, Dr Lu Yuanjiu, Dr Alvaro Azcarrago and Mr J. Harford. The 40th IAF Congress will be held in Beijing, China over the period 7th-13th October 1989. The theme will be "The Next 40 Years in Space".

Technical sessions included a number organised by the International Academy of Astronautics, which was established in 1960 to recognize individuals of great achievement and to promote the peaceful uses of outer space and co-operation between nations in the advancement of aerospace science. In fulfilling these purposes the Academy's 1000 members have established liaison with other international aerospace bodies and with several National Academies of Sciences, hence a joint meeting of the IAA and the Indian National Academy (INSA) – preceeding the Congress proper – was held in New Delhi on 7th October at INSA.

The morning session of the INSA was convened by B. M. Reddy, Head, Radio Sciences Division, National Physical Laboratory and consisted of six papers describing the work on Low Altitude Aeronomy in India.

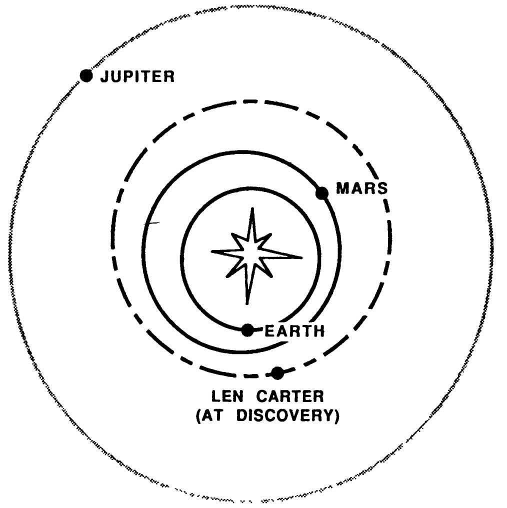
During the afternoon meeting, greetings from Dr George E. Muller, (President of the IAA) and Dr A. S. Paintal, (President of INSA) were presented to the delegates. The fourth IAA Scientific Lecture "Global Modelling and Space Data" was read by Prof. Jacques Louis Lions, President of the Centre National d'Etudes Spatiales (CNES) of Paris and member of the French Academy of Sciences.

Elections to the Academy included many well-known BIS Fellows, among them Jack Cherne, John Hodge, John Becklake, W. Geisler and Michael Michaud.



Asteroid Len Carter

In the *Minor Planet Circular* of August 27, 1988, it was announced that the asteroid formerly labelled 1979 MKL had been entered into the International Astronomical Union's (IAU) official catalog of asteroids as number 3817 and was named after Len Carter, Executive Secretary of the British Interplanetary Society. Discovered in 1979 by Eleanor F. Helin of JPL and S. J. Bus, a series of subsequent observations had allowed determination of a reliable orbit for the asteroid, and, hence, it became eligible for inclusion in the catalog.



Asteroid 3817 Len Carter's orbit lies in the main belt of asteroids between Mars and Jupiter. The configuration of bodies is shown for June 25, 1979 when the asteroid was discovered by E.F. Helin and S.J. Bus. *NASA/JPL*

The text of the IAU announcement reads:

> "Named in honor of Leonard J. Carter, executive secretary of the British Interplanetary Society. For more than 50 years, his efforts have been the basis for the constructive role of the BIS in space advocacy, education and international communications. Name proposed by the first discoverer [E. F. Helin] following a suggestion by W. I. McLaughlin and endorsed by R. L. Staehle."

Asteroid 3817 Len Carter is the story of two people: Carter and Helin.

In 1937, at the age of 15, Len Carter joined the British Interplanetary Society, four years after its founding. He was one of the leaders in resuming development of the Society after a hiatus due to World War II. Assuming the position of "interim Honorary Secretary" in June 1945, as a member of the committee planning the re-formation of the BIS, he was formally installed in the position when the Society was incorporated on December 31, 1945.

The path of Carter's career can be tracked by observing the growth of the BIS itself. See, for example, historical surveys by Frank Winter and Dr. L. R. Shepherd in the November 1983 and January 1985 issues of ***Spaceflight***, respectively.

My acquaintance with his work has been limited in time and scope but represents direct knowledge. Although we had some limited contact in the early 1970s with respect to publications, it wasn't until I began to make regular trips to England in 1976, in conjunction with the Infrared Astronomical Satellite (IRAS), that he and I got together on a more regular basis. The first occasions were visits to the small set of rooms in Bessborough Gardens which served as headquarters for the Society. When Carter talked about plans for the establishment of a more adequate site south of the Thames and the problems which such a move entailed, I came to realise the acumen and boldness of action of the undertaking. The present headquarters in South Lambeth Road is a facility of which all BIS members can be proud.

The quality of the Society's undertakings at all levels has been a concern of Carter: the wide-ranging collection of books in the BIS library (assembled in just a few years into a significant technical and historical resource); the Society's holdings in items of astronautical history; and programs of educational and scientific import, from specialized meetings to the Society's biennial space weekends (and hosting of the IAF Congress in 1987).

The most visible activity of the BIS is the publication of ***Spaceflight***, ***JBIS***, and occasional special studies. Carter's hand has supplied steady guidance along an upward path until, today, the voice of the BIS is a major contributor to the dialogue of the international space community. (On a mixed note, we have to hold him to account for asking me to begin the series of "Space at JPL" columns.)

It is a familiar observation that those imbedded in a period of historical change often fail to appreciate the flow of events about them. I remember sitting at the Saturday banquet at "Space 84", listening to Patrick Moore speaking in his inimitable style after dinner. When he said, "The Society exists today only because of the efforts of Len Carter", the material which I have sketched above clicked into place. Upon return to the U.S., I called Eleanor Helin and recommended that Carter enter the queue as a candidate for a named asteroid. The facts spoke for themselves, and four years later this event came to pass.

Eleanor Helin is a geologist by training, graduating from Occidental College in Los Angeles. In 1960, she joined the Lunar Lab at Caltech (the California Institute of Technology – Caltech – is JPL's parent organization). Hired by the geochemist Dr. Harrison Brown, she began work on analysis of the composition and structure of meteorites, extending these interests to statistical analyses of meteorite falls and finds.

Helen's career proceeded in a logical manner from meteorites to their larger brethren, asteroids. In the late 1960s, when she and Dr. Eugene Shoemaker

began research into near-Earth asteroids, there were only 8 or 10 of these objects known. Since that time, she and her team of investigators have concentrated on this category of celestial objects; over 100 near-Earth asteroids are now known, a figure due in no small part to their efforts.

Her first discovery of a near-Earth asteroid took place on July 4, 1973 using the 46 cm Schmidt telescope at Palomar, and the most recent asteroid of this class, discovered through the search programme, was picked up in August 1988 with the same instrument.

She reports that her team discovers two or three near-Earth asteroids per year, having to search approximately 13,000 square degrees of sky (almost one third of the celestial sphere) per asteroid discovery with a 46 cm Schmidt. Less amount of sky search, in square degrees, is required per discovery when the more powerful class of 122 cm Schmidt telescopes is utilized.

The search process with the smaller Schmidt employs a pair of 5-minute exposures of the same field separated by about one-half hour. The results are examined with a stereo microscope. To the trained eye, the slightly altered position of an asteroid will appear to levitate the image of that body into the third dimension above the general field of stars. The big Schmidt is used to take 60-minute exposures in the asteroid hunt. The exposure is not continuous; a time break is introduced to place a gap in the trail of the asteroid (the telescope is guided on the stars, which appear as point sources in the finished plate).

The presence of the gap allows one to eliminate the possibilities that the elongated image is due to a meteor, Earth satellite, or galaxy seen edge on. For a more complete review of the subject, see "Near-Earth Asteroid Searches: Status and Prospects," by E. F. Helin, in *The Evolution of the Small Bodies of the Solar System*, Soc. Italiana di Fisica, Bologna, 1987.

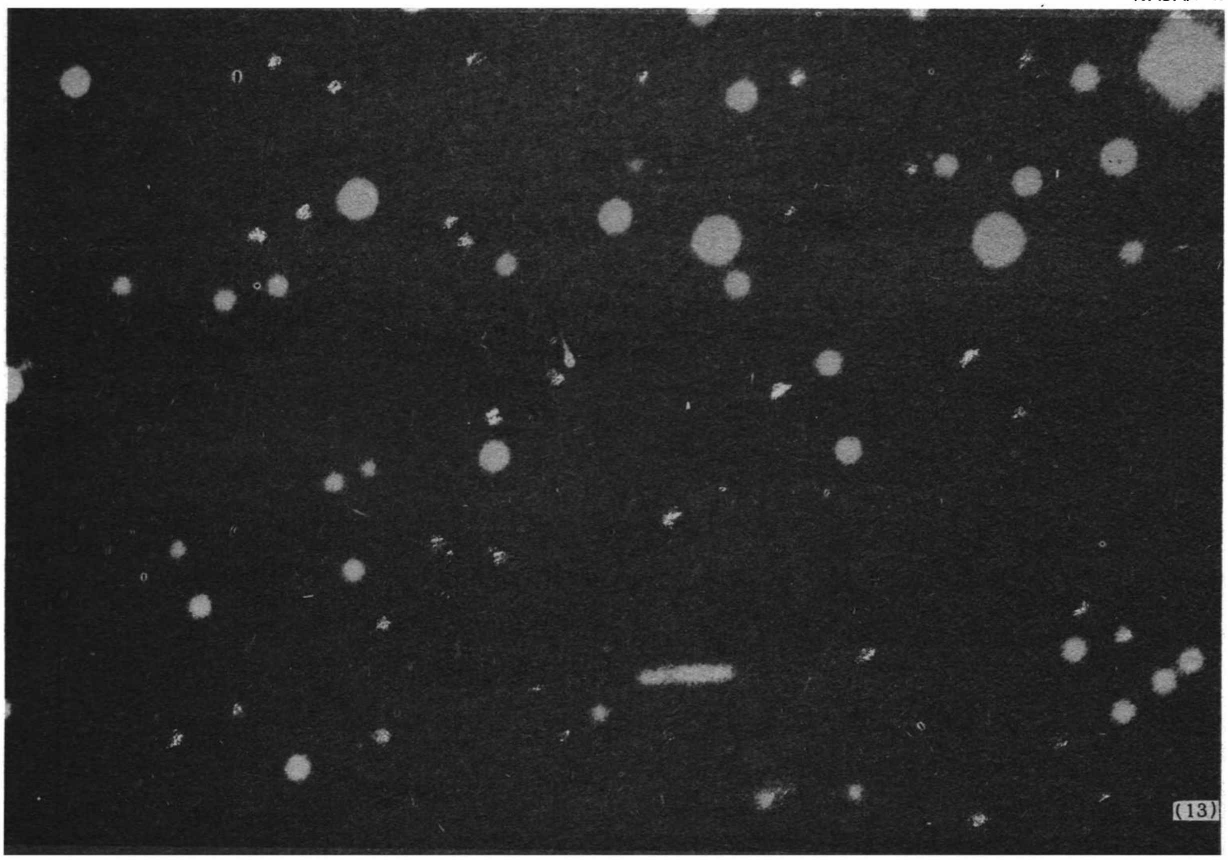
Asteroid 3817 Len Carter, with its semimajor axis of 2.27 AU and eccentricity of 0.11, plies the celestial routes between Mars and Jupiter, where the main belt of asteroids lies. Thus, it is not a near-Earth asteroid, but it represents a valuable scientific by-product of Helin's principal focus. In fact, her discoveries are numerically dominated by the classes of asteroids other than near-Earth objects. She estimates that she and her colleagues have contributed about 75 named asteroids to the catalog, and 406 "raw" (initial) discoveries were on her books for 1988 alone when we talked on November 1.

The selection of an appropriate asteroid is given careful thought by Helin when she is preparing to make an award (the IAU gives the discoverer of an asteroid the privilege of proposing its name, upon satisfaction of requirements concerning definite knowledge of its orbital elements). The asteroid which she selected for Len Carter was discovered (on June 25, 1979) at Siding Spring, Australia using the U.K. Schmidt, matching the ownership of the discovery instrument with the nationality of the recipient.

The award ceremony took place at "Space 88" in Hastings at the banquet on Saturday, October 1. Here, our two principals held centre stage as Eleanor Helin presented a plaque, with the discovery photograph and the official citation, to Len Carter. The interaction between these two accomplished people was one of those rare symbolic moments that give foundation to the thought that the world may be a rational place.

Afterwards, the general good feeling of the occasion was further augmented by a healthy sense of humour which bubbled through the evening. In mock indignation, Patrick Moore turned to Carter and said, "Your asteroid is bigger, brighter, and closer to the Sun than mine!" (Asteroid 2602 Moore was awarded to him in 1982 by the discoverer, Edward Bowell.) The Mayor of Hastings, the Honorable Mrs. Sandy Barr, said that the future might see use of the phrase "there is a beautiful, full Len Carter out tonight." The President of the Society, G. W. Childs, suggested that 100 years from now "Space 2088" might see the members holding their banquet on 10 km-diameter asteroid 3817 Len Carter, which, he said, would give a whole new meaning to the expression "dining out on Len."

Asteroid 3817 Len Carter is shown in this discovery photograph of June 25, 1979 as it moves through a star field in the constellation Capricornus.
NASA/JPL



Adventures in Software

The public face of the space program is replete with launch vehicles, images of distant worlds, astronauts and cosmonauts, funding shortfalls, and other familiar themes. Software – the computer programs and data that drive computer systems – is rarely discussed outside of specialised forums unless it has led a computer to do something exceptionally "dumb" or, at the other extreme, is reputed to codify near-human capabilities. In fact, a substantive fraction of the work of developing space systems is invested in producing flight and ground software to animate the more visible paraphernalia: hardware.

In a topic as extensive as machine computation, it is difficult to assign proper historical credit for advances, but the Hungarian-American mathematician John von Neumann (1903–1957) was a major contributor to the development in the 1940s of stored programs for real machines. In his paper, "From ENIAC to the Stored-Program Computer: Two Revolutions in Computers" (in *A History of Computing in the Twentieth Century*, Academic Press, 1980), Arthur Burks states: "His [von Neumann's] variable address EDVAC code was the basis of the modern computer software 'revolution." EDVAC was a computer developed at the Moore School of Electrical Engineering, University of Pennsylvania. The first revolution to which Burks's paper refers was accomplished with the construction of the ENIAC machine, a project begun in 1943 at the Moore school, "It was the first electronic, digital, general purpose scientific computer, and it computed 1000 times faster than its electromechanical competitors."

Languages for mediating between humans (programmers) and machines are continually being developed to meet the growing needs of users; one of the most successful languages, FORTRAN, was created in the mid-1950s.

A simple taxonomy of software for space applications distinguishes between flight and ground software. The former category, software carried onboard the spacecraft, can be further subdivided into programs, in more-or-less permanent residence, which provide the basis for spacecraft operations, and programs which carry out the mission plan and must be continually renewed as the mission progresses ("sequences"; see the following piece on ESOC).

Ground software systems are huge; JPL project and multimission program sets are built from millions of lines of code. My first involvement with ground software came in 1971 when I assumed the lead engineering role in developing the trajectory program for the Viking mission to Mars (1975 launch). The Program, DPTRAJ for "Double Precision Trajectory", was used for computing the flight paths for the two Viking orbiters during their interplanetary and Mars-orbit phases. It was derived from earlier trajectory programs, and its descendant flourishes to the present day at the Laboratory. (An historical survey of DPTRAJ and several other major JPL pieces of ground software is contained in my paper AIAA-88-0547, "Mission Operations Systems for Planetary Exploration", co-authored with D.M. Wolff and presented at the Aerospace Sciences Meeting in Reno, Nevada, in January 1988 TRP e.g. 1988.).

After more than two years of work on requirements analysis, design, and production of the computer code by our DPTRAJ team, the program was ready for testing prior to formal delivery to the Viking project. Testing involved two fundamental techniques: (1) comparisons of DPTRAJ results with those obtained by running earlier versions of the trajectory program ("regression testing"), and (2) independent calculation of special cases representing new Viking capabilities, and comparison of these cases with the numerical opinion of DPTRAJ.

Whatever shreds of sanity I emerged with after three months of testing, under schedule pressure, were undoubtedly preserved through the fortuitous advent of a new technology: the pocket calculator. I well remember the new-found ease with which the HP-45 calculator allowed construction of those special cases against which DPTRAJ could be judged. Prior to the invention of these delightful devices, engineers usually had to resort to consulting cumbersome tables of logarithmic and trigonometric functions and performing laborious interpolations by hand. But all is relative; one imagines the joy that spread through seventeenth century Europe when John Napier (1550–1617) conceived of the idea of logarithms and Henry Briggs (1556–1631) produced the logarithmic tables so useful in the simplification of calculations.

The unsophisticated methodology which I employed in testing the Viking version of DPTRAJ to free it from errors has been considerably improved in the last decade and a half. A conference, "Improving Software Quality", was held in Pasadena on July 13, 1988 under the sponsorship of the NASA Software Management and Assurance Program and JPL. A presentation by Al Pietrasanta, long a key manager at IBM, characterised the evolution of software quality from 1960 to the end of the century.

Pietrasanta said that statistical studies have shown that programmers introduce about 60 errors per thousand lines of code. Throughout the 1960s and 1970s the number of errors per thousand lines of code in the finished product decreased through improvements in the programmer's art and better methods of error detection. Late error detection, such as I pursued in DPTRAJ testing, cannot be expected to reduce the error rate to much less than 10.0 per thousand lines of code. However, in the 1970s the early detection of errors began to be emphasized, and a new spiral of error reduction was triggered. A software inspection technique created by Michael E. Fagan of IBM, who also spoke at the Pasadena conference, was a major factor in the drive for quality, and rates as low as 1.0 began to appear. Fagan's inspections probe each phase of the life cycle, from requirements through design and coding rather than just detecting errors at the end of the life cycle, prior to delivery of the program.

Current practice, emphasizing prevention, can yield error rates of about 0.1 in the delivered computer program. Pietrasanta sees the error rate going to 0.01 and even lower in the next decade. The quest for "zero defects" will be greatly assisted by automation of portions of the software-generation process.

The benefits of low error rates are of importance to mission success and dollar savings. It is not surprising that one of the strongest and most successful software-quality efforts has been conducted by IBM's System Integration Program at Houston in support of the Space Shuttle. In addition, intensive software inspections have been shown to pay for themselves, and more, by reducing the test time required in flushing out errors at the end of the software life cycle; testing a clean product goes swiftly and easily.

My wife, Karen B. McLaughlin, a systems analyst at JPL currently working on software standards, reminds me that I would be remiss not to go beyond the subject of software quality to address the larger topic of standards. Software standards are prescribed for the development process in order to insure application of the best methods throughout an institution, in this case JPL.

Software management standards address a wide class of subjects: contents of the software management plan, phases of the software life cycle, structure of the development organization, reviews (which could include software inspections), required documentation, software metrics used to monitor progress and quality, etc.

The ability to transfer some human control, through a stored program, to the rapid and accurate circuits of a machine is not only of value in space applications, or even engineering and science in-the-large, but also features prominently in the development of modern mathematics. Numerical experimentation and even the proof of some theorems have been accomplished using computers, but, to date, the most profound influence on mathematics has come through thinking about the nature of computation rather than through carrying out computations.

The English mathematician Alan M. Turing (1912–1954) was a theoretician of great originality and also played an important role in pioneering computer work in Britain during World War II. At Bletchley Park, Buckinghamshire, Turing and his colleagues worked to break the German code, among other activities.

One of Turing's most influential concepts was the Turing machine, as it has come to be called, presented in a 1936 paper. The Turing machine is a (usually) hypothetical device which is able to read and write on a tape of (potentially) infinite length. The tape is divided into cells of equal lengths and at most one symbol can appear in each cell; there is no loss of generality to assume that only two types of symbols, "0" and "1", are employed.

The Turing machine has two other features. First, at any one time it is characterized by being in one of a finite number of "states". Second, it contains a list of instructions on how to act and what state to go to after each action. The operation of a Turing machine begins when it reads the contents of its first

cell on the tape. The machine takes action based only on the contents of the cell and the current state of the machine. Only four actions are possible: move the tape one cell to the left, or move the tape one cell to the right, or write a "O" in the cell being read (erasing the previous contents), or write a "1' in the cell being read The Turing machine then assumes its next prescribed state, which can be the special state that tells the machine to halt, or, if the job is not done, it reads another cell on the tape and continues to compute

That is all there is to the concept, but the consequences are considerable. Despite the simplicity of the definition of a Turing machine, it captures the idea of everything a computer can do. Even using the most complex circuitry, no computer can, in principle, accomplish more than Turing's simple box with a tape running through it (if, of course, the Turing machine were given enough time to lumber through its computations). Any one Turing machine, with its list of instructions, can be thought of as instantiating an algorithm. For example, the data on the input tape it reads could represent a positive number (in binary notation), and the machine could be equipped with a list of instructions which would always result in it printing on the tape the (possibly truncated) square root of the number it read.

With some additional conceptual effort, the simple Turing machine can be transformed into a more flexible device called the Universal Turing Machine (UTM). The UTM does not depend upon its fixed set of instructions alone, but rather this set is supplemented by a stored program P which, coded into a binary string of O's and 1's, is read into the UTM on the tape along with the binary string of data D. The result of operating the UTM is the same as if a Turing machine with fixed set of instructions P had operated on data D. Roughly speaking, the transition from Turing machine to UTM is like that from ENIAC to EDVAC.

Turing used his machine representation to prove the unsolvability of what is called the halting problem. The problem is to determine in some mechanical (algorithmic) fashion whether P operating on D will ever halt (or will the machine keep running forever).

Turing applied his UTM to the halting problem by considering program P and data D, taken together to be a new data set, to be operated upon by a "master program" M for the UTM. He showed that there does not exist any such program M which would operate on P and D and always be able to indicate whether this program/data pair P/D would ever halt if used, itself, to drive a Turing Machine. No matter what master program M is devised, there is always some P/D pair for which it cannot predict if the pair would yield a finite run for a machine. That is, there is no automatic or algorithmic method of always determining beforehand how long a program and its data will run. In general, the only way to see if a computation will halt is to watch it in action and wait for it to halt.

The halting problem is closely related to the "decision problem" Given a statement S of mathematics (a theorem), is it always possible to establish mechanically whether S can be proved or not? (Note· "yes" or "no" is all that is asked for, the proof itself is not required.) It was shown (by Alonzo Church in 1936), that, in effect, there is no UTM which will gobble up statements and produce the required answer· the decision problem is also unsolvable. The best that can be done with regard to the decision problem for S is to take the basic set of axioms and start grinding out proofs of theorems: all proofs of length one, all of length two, etc. If the desired theorem S ever turns up, it is, *a posteriori*, provable But, the process may continue forever without producing S. (The relationship of the decision and halting problems is apparent)

Turing machines are also useful in an allied area; defining the complexity of a given object, say, a number. A number consisting of an infinite string of 1's is intuitively much simpler than a (binary) number consisting of a random string of O's and 1's The U-complexity of a number N is defined as the length of the shortest program P which will result in the Turing machine U printing out N, i.e., the length of an efficient recipe for N. For random strings N, the complexity of N is about equal to the length of the string representing N.

One of the founders of "algorithmic information theory", Gregory Chaitin of IBM, has said of mathematical complexity· "You can't prove a twenty-pound theorem with a ten-pound theory" An interpretation of Chaitin's statement is that a finite entity – be it a mathematical theory, a Turing machine, or a human – has limits on its ability to comprehend its environment. See Rudy Rucker's 1987 book *Mind Tools* (Houghton Mifflin Co., Boston) for a readable account of the limits that complexity imposes on the acquisition of knowledge.

Rephrasing Chaitin for the context of the search for extraterrestrial intelligence (SETI)· could an N-bit human recognize, say, an N^2-bit extraterrestrial? The May 1986 edition of this column explores some relations between SETI and the theory of knowledge.

Control of spacecraft, problems of abstract mathematics, and questions in exobiology illustrate the scope and power of the entities we classify as software.

European Space Operations Centre

Operations constitute a major component of every space programme, and the European Space Operations Centre (ESOC) is one of the world's premiere facilities for the control of missions beyond the atmosphere. Located in Darmstadt, Federal Republic of Germany, ESOC contains a broad range of capabilities related to flight practices, ground systems, and associated technology development. My visit to ESOC in October 1988 was made for the purpose of learning from the experience of this institution accumulated over a period of more than 20 years.

The main building at ESOC. *ESA*

The establishment of ESOC took place in September 1967, and the facility was fully operational by May 1968. Currently, about 650 people are employed at the Darmstadt location; approximately 300 belong to the European Space Agency (ESA) and the remainder are contractor personnel. There is a balance of various European nationals at ESOC as befits an ESA installation.

Kurt Heftman, as the Director of Operations for ESA, heads ESOC and reports to the Director General of ESA, Professor Reimar Lüst, along with seven other ESA directors. An Austrian citizen, Heftman assumed his present position in 1983 after retiring from JPL as a member of the senior technical staff, encompassing a 24-year career in which he participated in a large number of space projects from Ranger and Surveyor through Viking, Helios, and Voyager. At ESOC the deep-space facet of his career continued to shine with the successful 1986 flyby of Halley's Comet by Giotto.

The hierarchical structure of ESOC proceeds from "Department", of which there are five, down through "Division", "Section", and "Group". Heftman said that he holds in-depth staff meetings with his Department heads about every two weeks and, in turn, reports to ESA Headquarters in Paris with the same frequency. The connection with Paris exemplifies the distributed nature of the ESA enterprise, and the successful methods of co-ordination practiced within the Agency are of interest to all of us who must operate within an increasingly inter-connected environment.

Project management generally resides at the European Space Research and Technology Centre (ESTEC) at Noordwijk, The Netherlands. Representation of a project, such as Giotto or the Infrared Space Observatory (ISO: scheduled for a 1993 launch), at ESOC is effected through a Ground Segment Manager (GSM) within the Systems and Project Support Department at Darmstadt.

At launch, a spacecraft is operated under the control of the Flight Operations Director and his team from the large Main Control room. In a directly adjoining area is the Flight Dynamics room from which navigational and attitude-control functions are carried out.

After a project enters the routine operations phase, the flight team transfers to a dedicated facility, an Operations Control Centre, for the remainder of the mission. At the time of my visit, ESOC was supporting 10 missions in flight. Tracking and commanding support in all phases of the mission is provided by the network of ESA ground stations: ESTRACK. See also the June 1987 edition of ***JBIS***, which is devoted to ESOC (the June 1988 issue of *Interdisciplinary Science Reviews*, devoted wholly to ESA, is also relevant).

A tour of the Meteosat control center, in company with Dr. Johannes Schmetz, a staff meteorologist, revealed an array of video displays for telemetry and, in addition, facilities for processing the scientific data continually being returned by the satellite.

The Meteosat series entered its operational program in November 1983 and will continue until at least 1995. The satellite is positioned at the intersection of the Greenwich prime meridian and the equator (0 degrees longitude, 0 degrees latitude) at geosynchronous altitude, almost 36,000 km. The 320 kg (initial mass) satellite images the hemisphere every half hour in the visible and two bands of the infrared spectrum.

The Meteosat images are dissected into 6400 segments which are selectively processed by Schmetz and his colleagues to yield seven meteorological products describing winds, temperature, cloud cover, precipitation, etc. It was enlightening to a lay observer such as myself merely to observe a movie of changing cloud cover over Europe assembled from a series of Meteosat images.

The first in the Eureca (EUropean REtrievable CArrier) series of Earth satellites is scheduled for launch in 1991. It will be released from the Shuttle to conduct 15 scientific and engineering experiments over a period of approximately six months, when it will be retrieved by the Shuttle. Among the experiments are: crystal growth, variability of the solar spectrum, variations in solar luminosity, Earth-atmosphere studies, X-ray transient measurements, microparticle population sources, and solar-cell performance.

The Eureca mission was of particular interest to me because, after launch, the spacecraft will be controlled by sequences of time-tagged commands stored onboard. A common alternative, as with Meteosat, is to send up "real-time commands" which are acted upon by the spacecraft immediately upon receipt. My interest was based upon the fact that JPL spacecraft, generally operating at great distances from Earth, are controlled by stored sequences, with real-time commanding employed only as a supplement (see *"How to Feed a Spacecraft"* in the January 1987 edition of this column).

Kurt Aubeck, the GSM for Eureca, said that a "Master Schedule" (sequence of time-tagged commands) would be up-linked to the spacecraft every 24 hours, to cover the next 48 hours. Then, the succeeding uplink, a day later, would update the remaining 24 hours of the resident Master Schedule, if necessary, and, with its 48-hour span, add a new 24 hours of commands.

The criterion which was applied to decide upon stored commands – Master Schedules – versus real-time commands was geometrical; in its low Earth orbit, station passes by Eureca would be relatively short events and not suitable for full-orbit control via the real-time route. Meteosat, in its geosynchronous orbit, satisfied the geometrical criterion to be operable by real-time commanding.

One of the pleasures of circulating through the space community is meeting colleagues from past missions. The Eureca Spacecraft Operations Manager, Jan van Casteren of The Netherlands, and I continued the discussion of Eureca and renewed our acquaintance established when we both worked on the Infrared Astronomical Satellite (IRAS) earlier in the decade. The Mission Planning Aid and the Master Schedule Generator programs which van Casteren and his associates are developing were of interest since they address many of the same needs with which we are tasked in our flight projects at JPL.

The method for controlling the astronomical satellite ISO, according to the GSM, Andrew Robson, is a kind of hybrid. While the spacecraft will not be equipped with the capability to carry onboard sequences, mission planning requirements have led to a plan to store a two-day backlog of real-time commands in a ground computer and squirt them up as needed. The planning cycle itself will be two weeks in length.

Technology development is important for a space operations organization in order to satisfy the requirements of ever more demanding missions and to control costs through automation. Herwig A. Laue heads the System Engineering and Mission Analysis Division at ESOC, and we discussed technological research which he is supervising.

Expert systems prototyping of an operations adviser for the power system of a communications satellite is being undertaken. The two goals he has established are frequently seen with regard to expert systems; reduction of workforce and capturing expert knowledge in a computer program rather than relying on the memories of humans who can forget or disappear.

Another area of research concerns human-machine interfaces in the use of video displays: the best use of colour, promotion of common symbology among projects, and whether or not it is useful to provide the text of flight operations plans on video screens. Laue said that he would also like to develop a mission analysis assistant. Such a piece of software could, after having been given overall objectives, draw upon a large library of computer programs, set up the requisite files, and run the programs to produce, automatically, a mission analysis. For example, one might specify a flight to Mars with an Ariane 5 launch at a certain date and a specified flyby altitude at the planet. Trajectory details, including a possible atmospheric probe release, would be calculated by the mission analysis assistant.

After two days of talking to people, I again stopped by Kurt Heftman's office to say thanks for the hospitality and the information. I told him what he already knew: that he has a first-class team. The exciting program being undertaken by ESA will continue to be well served by its ESOC component.

ESA's Ten-Year Success Story

To mark the tenth Anniversary of ESA's communications satellite operations *David Wilkins*, Head of Spacecraft Operations Division at ESA's European Space Operations Centre (ESOC) and Fellow of the BIS looks back over this little-publicised success story*

In the 1970's the European Space Agency saw a tremendous potential for communications satellites and set about developing its first experimental telecommunications satellite.

Nowadays, when communications satellites no longer make the headlines, it is easy to overlook the excitement which accompanied this new technology and the part played by ESA in promoting European know-how in such an economically important field.

On May 12, 1978 ESA's Orbital Test Satellite, OTS, was successfully launched, marking the beginning of a series of communications satellites developed and operated by the Agency. This series, which includes the operational satellites ECS and Marecs designed for use by Eutelsat and Inmarsat, will be extended with the launch of the Olympus satellite, followed in the next decade by experimental satellites under the Agency's Payload and Spacecraft Development and Experimentation Programme and the operational satellites which will form part of its Data Relay Satellite Network. OTS was not only at the start of all these ESA programmes, but was also the forerunner of a large number of sales by European industry of communications satellites for national and international networks.

This pioneer spacecraft was initially intended for a period of three years in orbit. Now, ten years after its launch, the OTS spacecraft is still fully functional and capable of providing useful communications services.

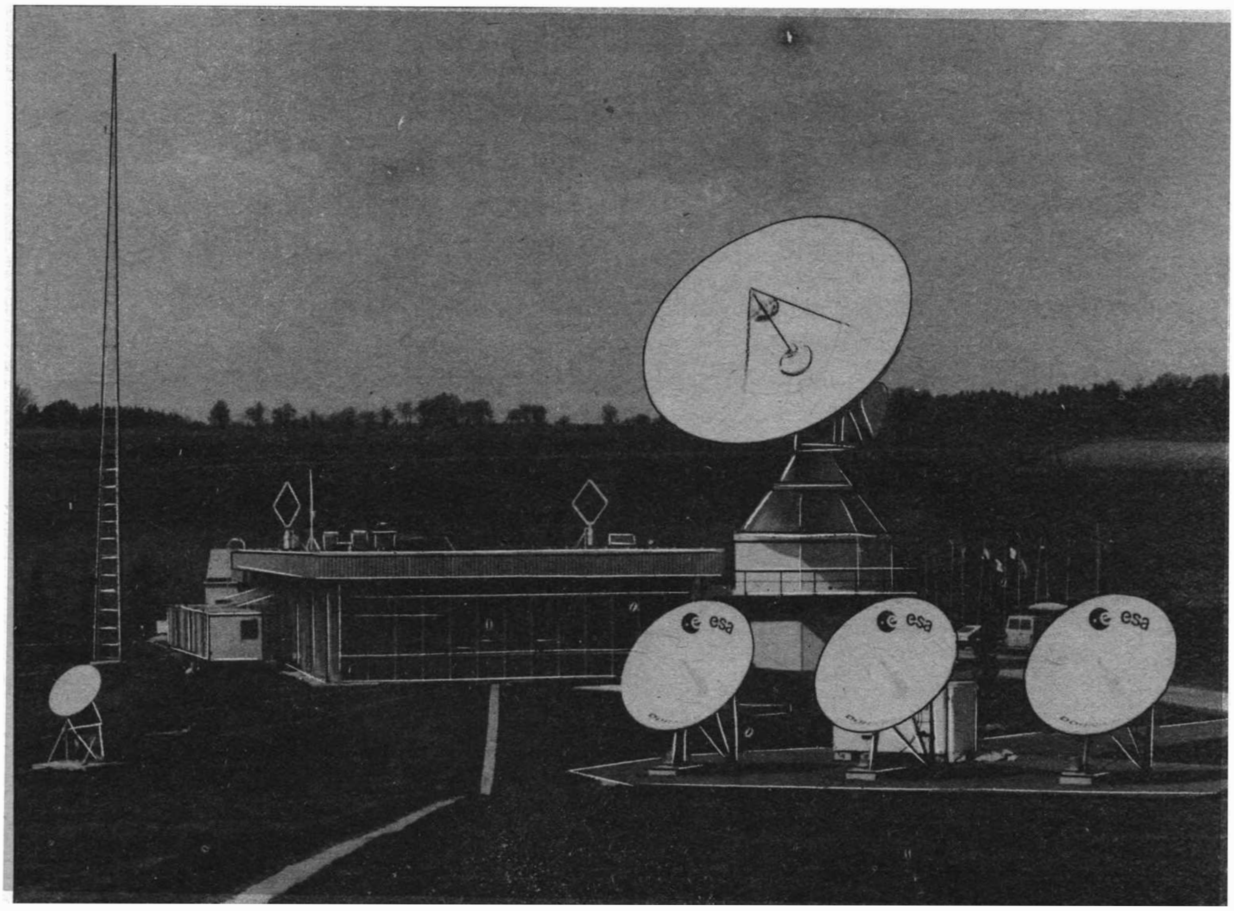
It is difficult to realize that more than ten years have passed since May 11, 1978 when OTS-2 began its journey towards orbit for a planned lifetime of 3 years. It is also difficult to realize that in the short time between September 13, 1977 when OTS-1 was destroyed by a Delta launcher explosion, and May 1978 a second OTS was constructed, tested and made ready for launch.

The night of September 13, 1977 is one that has many personal memories. I can still hear the announcement as it came clearly over the launch coordination circuit from Cape Canaveral "The vehicle has been destroyed". Our telemetry data from OTS

Continued p.20

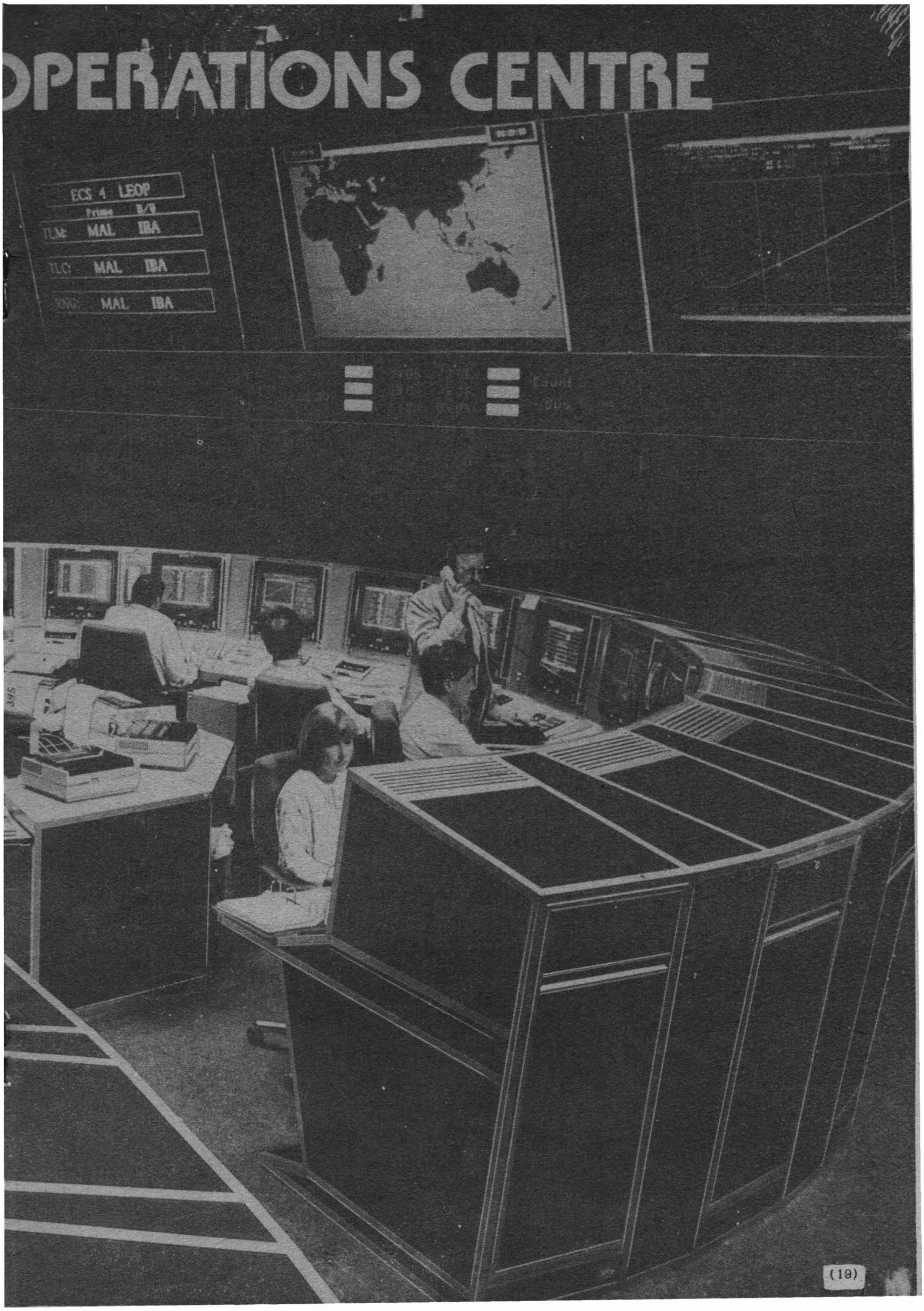
* Based on a lecture entitled "Communications Satellite Operations" presented at the 10th Anniversary Celebration of the OTS Mission, ESTEC, Noordwijk, The Netherlands on May 26, 1988.

The ECS antennas at the ESA Redu ground station in Belgium. *ESA*



EUROPEAN SPACE C

OPERATIONS CENTRE



Continued from p.17

which was being processed for some hours before launch at ESOC had ceased abruptly at 55 secs after liftoff making the mission of OTS-1 the shortest of all ESA missions. It is fitting that we pay tribute to the success of OTS-2 (which has been the longest mission of any ESA spacecraft) and to consider the experience which both ESOC, ESTEC and the Communications Programme gained from the in orbit operations of OTS and subsequent satellites.

What have we learned from OTS? It is useful to consider the history of operations activity in 1977/1978:

20 April 1977–GEOS-1
13 September 1977–OTS-1
22 October 1977–ISEE-B
23 November 1977–Meteosat-1
26 January 1978–IUE
11 May 1978–OTS-2
14 July 1978–GEOS-2

During a period of 15 months the Agency was involved in seven launch and orbital operations with an extremely heavy load on the Control Centre Staff. OTS was the first ESA 3-axis spacecraft using a complex AOCS (Attitude, Orbit Control System) and requiring high precision station-keeping. From the detailed Flight Operations Plan (FOP) prepared for GEOS, the first scientific geostationary spacecraft, a basic standard for future FOP's was developed. But in the case of OTS it was possible to use the ESOC main-frame computer to automate to some extent the preparation of FOP's. From this period of heavy operational activity we therefore gained both a standard method of Flight Planning and a computer-aided method of documentation development which has been in use with some minor changes since then. Of course today we use word-processors rather than mainframe computers but the basic Flight Planning and Flight Control Procedures were developed during the OTS mission preparation.

Since OTS was essentially a test satellite it was vital that a very exact method of reporting be established between the flight operations team at Darmstadt, the project team at ESTEC and the in-orbit test team at Fucino. This system of reporting, which led to the use of Spacecraft Anomaly Reports being issued from the Spacecraft Operations Manager at ESOC to the Project Manager with a wide distribution, has become a standard method of reporting for all ESA missions.

Orbital Operations

The initial phase of any geostationary mission is called the LEOP (Launch and Early Orbit Phase) and is the most critical in terms of spacecraft safety. Fig. 1 shows this sequence for a Marecs spacecraft, but the ECS/Marecs LEOP activities are very similar. The spinup and spindown sequences followed by Sun acquisition and Earth acquisition are similar in both cases. The need for rapid and accurate orbit determination was recognized early in 1975 and the flight dynamics software used at ESOC for all GTO (Geostationary Transfer Orbit) operations since 1977 has provided accurate and rapid results for orbit determination, attitude determination and manoeuvre support and were first used with OTS. For example in the case of ECS-4 the total fuel consumed between launch to orbit and first station acquisition was 8 kg out of a total of 119 kg loaded at launch. This was 6.8 kg less fuel than was predicted for this task. This means that approximately 6 months have been added to the planned lifetime of ECS-4 as a result of precise GTO operations.

In late 1981 Marecs-A was launched and placed on station according to plan. After some initial problems with onboard systems the operations control methods were modified and Marecs-A has been controlled from ESOC for the last six years. We hope to celebrate a tenth anniversary of Marecs-A in December 1991. Marecs-B2, launched in November 1984, has provided uninterrupted service to Inmarsat since February 1985.

In late 1985 ESOC was requested by Inmarsat to transpose the two Marecs satellites, i.e. to position Marecs-A in the Pacific region replacing Marecs-B and to position Marecs-B in the Atlantic region. This move provided Inmar-

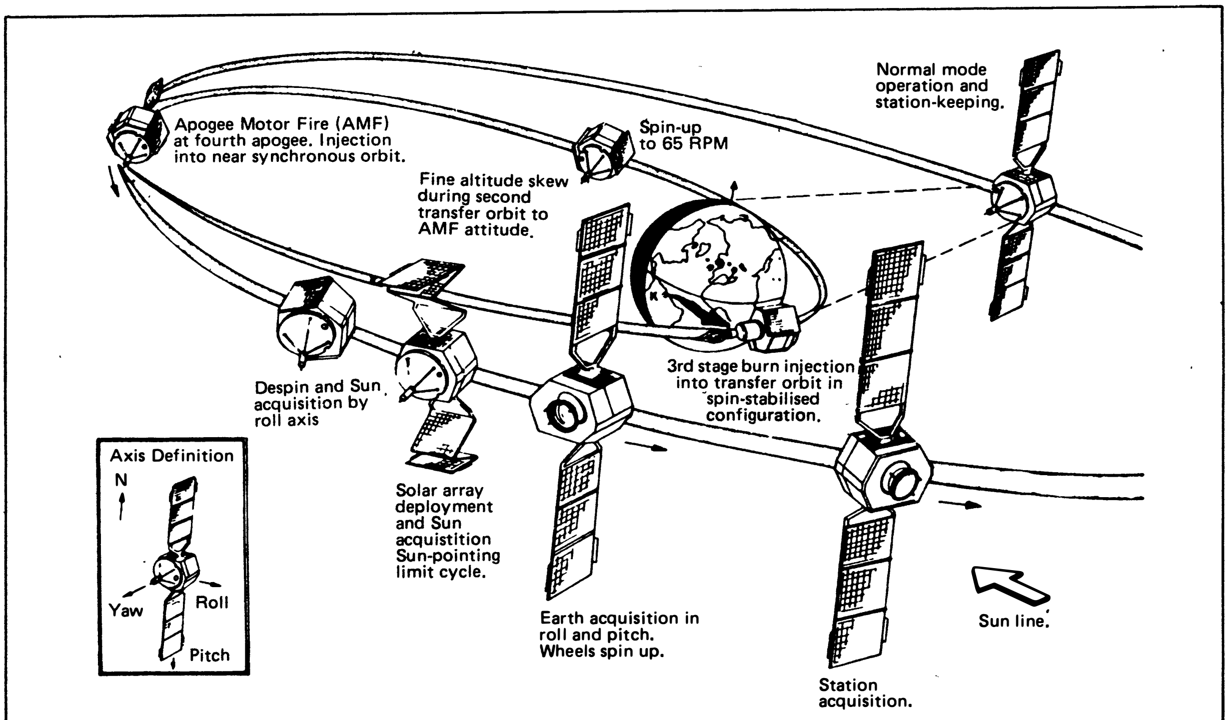


Fig. 1 MARECS SPACECRAFT TYPICAL FLIGHT PATH

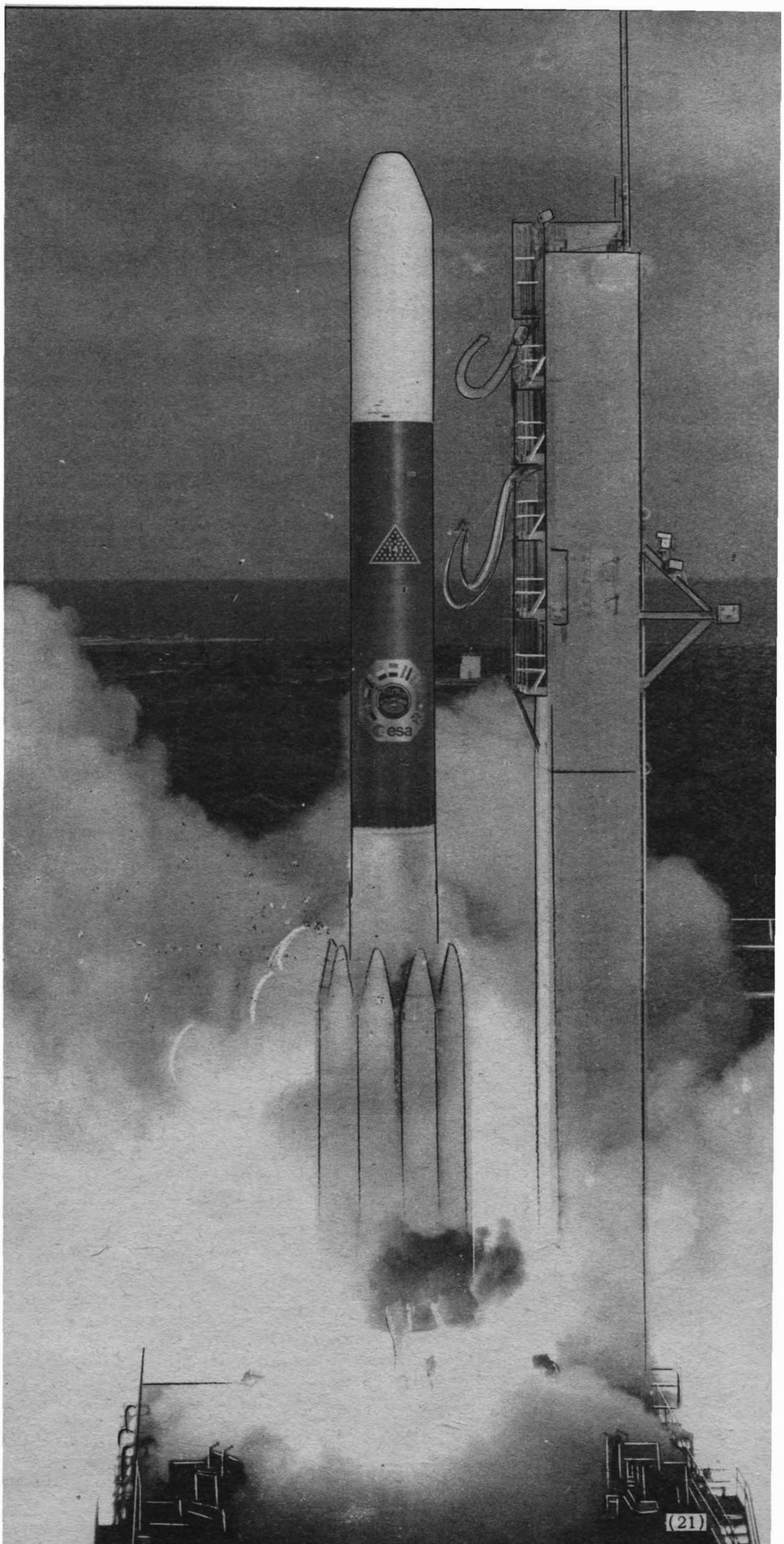
sat with a higher level of availability in the heavy traffic Atlantic region. The relocation process which began on January 13, 1986 and which was completed on May 12, 1986 required both spacecraft to be manoeuvred more than 200 degrees along the equatorial plane. The control of Marecs-B2 located at 26 degrees West is accomplished from ESOC via the ESA station at Villafranca near Madrid, while we control Marecs-A located at 176 degrees East via the Ibaraki station which is north of Tokyo.

ECS-1 was launched in June 1983 and for the first time an ESA spacecraft was operated at a distant control centre. The LEOP operations were conducted from ESOC but once the first station acquisition had been completed, operations were transferred to the newly-built ECS Control Centre at the ESA Redu Station in Belgium. This control centre designed to standards used at ESOC and using identical software systems is now operating ECS-1, ECS-2, ECS-4 and is awaiting the launch of ECS-5 which will be initially controlled during LEOP from ESOC and then handed over to Redu for on-orbit operations.

ESOC Experience

As we look back over the past ten years we realize that the agency has developed a broadly based expertise in the field of communications satellites from the nucleus of the OTS project. As an operations manager I feel that we have established an experienced team of experts at ESOC in all fields of expertise necessary to ensure the success of ESA communications missions. It is interesting to note that the Mission Operations Managers for both the ECS and Marecs missions together with several of their control team staff are all graduates of the OTS mission control team. Today tasks such as ABM Firing, GTO operations, Stationkeeping, Battery Reconditioning, Eclipse Operations and Solar Sailing, while not treated as merely routine are recognized as normal functions for our control centres. Before the launch of OTS we considered all of these activities with some trepidation.

ESOC has now conducted LEOP operations for 10 geostationary missions, six of these being communications satellites which are still in orbit. We look forward to the launch of Olympus in 1989 and to the challenge which that mission will imply. We also look forward to DRS (Data Relay Satellite) and the era of manned space flight when communications will truly be the vital link upon which mission success will depend.



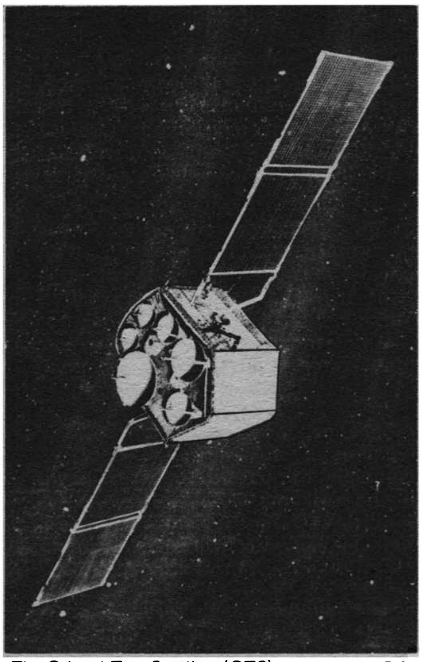
A Delta launches the European OTS-2 satellite in May 1978. *ESA*

TELECOMMUNICATIONS: THE OTS LEGACY

When you telephone Sydney, telex Tokyo or send computer data to New York, the odds are good that you will be using a communication satellite. Only a third of international tele-traffic goes by cable laid beneath the Oceans. The rest goes via satellites which have unique qualities that set them apart from other transmission media such as coaxial cables, optical fibres and radio links. Telecommunication satellites are injected into a geostationery orbit some 36,000 km above the Equator. Today there are more than 100 such telecommunication satellites orbiting the Earth.

They make it possible to establish wide-band links across considerable distances. Because satellites allow both multiple access at the transmitting end, and multiple destinations at the receiving end, links can be switched easily, with no need to switch centres.

Transferring information was important back in the Middle Ages – the era of information is not new – but telecommunications have pushed back the limits of the possible. Today, sounds, words, pictures and electronic data are transmitted at the speed of light: telecommunications have become the most dominant factor affecting commercial and social life.



The Orbital Test Satellite (OTS). *BAe*

The Orbital Test Satellite (OTS)

ESA became aware at an early stage that communications satellites have tremendous potential.

The European space Agency's first experimental telecommunication satellite was developed in the 70's and put into orbit in May 1978. Although it had a planned life-time of only three years, OTS continues to be operational and celebrates its tenth anniversary in orbit this year.

"OTS was developed to provide in-orbit verification of the technology to be used on the future ECS (European Communication Satellite) system and to provide the European PTT administrations with pre-operational satellite communications capacity" says René Collette, Head of Communication Programme Department at ESTEC. "By developing a European regional system, the Agency aimed at helping European countries to achieve commercial success and to acquire a significant share of the world market in this field. OTS also carried out a series of tests and experiments on radio-wave transmission through the atmosphere, frequency re-use, etc."

OTS was launched on May 11, 1978 from Cape Canaveral by a Thor Delta rocket, replacing an identical satellite, OTS-1, which was destroyed in September 1977 when its launcher exploded shortly after lift-off.

OTS is a three-axis stabilized geostationary satellite, consisting of a service module and a communications module carrying the payload.

At the beginning of its life in geostationary orbit OTS weighed 444 kg including its provision of fuel. The spacecraft is 2.39 m high, 2.13 m long and spans 9.26 m with its solar arrays deployed.

The satellite was designed at ESA's European Space Research and Technology Centre (ESTEC) in the Netherlands and built by a consortium of European companies led by British Aerospace.

To take advantage of the capacity provided by the OTS satellite a number of Earth stations were set up throughout Europe. The first one was built by ESA in collaboration with Telespazio at Fucino in Italy. The spacecraft Control Centre at ESOC controls the satellite's configuration and gathers information on its service functions via the Satellite Control and Test Earth Station (STSC) in Fucino.

Constant liaison was also established with other Agency stations at Villafranca, Dublin and Stockholm.

OTS successfully carried the hopes of Europeans anxious to improve the quality of their telecommunications and explore new technologies and techniques with worthwhile applications in the business world and in every-day life.

ECS

As OTS was being tested, ESA was preparing to launch its successors. The ECS series, of proven commercial interest and success, are operated by the European Telecommunications Satellites Organisation, Eutelsat, representing the European PTT's, which was set up in 1982 for the operation of a European regional satellite telecommunication system.

ECS-1, launched by Ariane in June 1983 can carry 12,000 telephone calls simultaneously. The ECS satellites have a 3-axis stabilized configuration based on OTS. All the communication antennas of the ECS-1 spacecraft are of the centre-fed type derived from the OTS programme.

However, ECS-2, which was launched on August the 4th 1984, has a new type of antenna with a multi-service receive/transmit function, which is more powerful and has a larger bandwidth capability. ECS-3 and ECS-4 (launched in September 1985 and September 1987) have the same type of antenna as does ECS-5 which was launched in July 1988.

Telecommunication satellites developed by the European Space Agency have inspired other European derivatives: Skynet 4 used by the British Forces, Nato 4, French Telecom, and the Eurostar family of satellites developed by Satcom International, an industrial consortium.

Mobile Communications For Land and Sea

In December 1981 Ariane launched the first maritime communications satellite Marecs-A from Kourou in French Guiana. Three years later Marecs-B2 was also successfully launched by Ariane from Kourou.

The two Marecs satellites are leased from the European Space Agency by Inmarsat, the International Maritime Satellite Organisation.

The Marecs satellites serve as operational satellites covering the Atlantic and Pacific Ocean region. Marecs-B2 provides ships within the Atlantic Ocean region with a variety of commercial maritime telecommunications services including voice, teletype, facsimile and high-speed data, while Marecs-A covers the Pacific Ocean. Originally, Marecs A was located over the Atlantic and Marecs-B2 over the Pacific but the satellites were interchanged last year to take advantage of the more powerful Marecs-B2

ESA is taking another step forward in developing satellite communications to the shipping and off-shore industries: The Advanced Repeater for Aeronautical and Maritime Integrated Services, ARAMIS, will use sophisticated phase-array antenna techniques. The satellite will generate spot beams that can be directed from orbit to anywhere on the Earth's surface, enabling communications services to become cost-effective for aeroplanes and small ships and boats.

ESA is also developing mobile communications for land-based vehicles such as lorries or even personal cars. Under a programme called PRODAT, the Agency had demonstrated the efficiency of small terminals mounted on land vehicles and aeroplanes, allowing a two-way data communications link between the vehicles and suitable ground stations.

This technology can form the basis for an extensive land-mobile system within Europe. Not only could this bring immediate commercial benefits, but PRODAT could also foster a large export market for European industry to developing nations, where such communications services are sorely needed.

Olympus, the Future in Advance

With the exploitation of ECS and Marecs satellites safely in the hands of Eutelsat and Inmarsat and their control now a routine function of ESOC, the Agency has turned its attention to the next generation of larger and more powerful satellites.

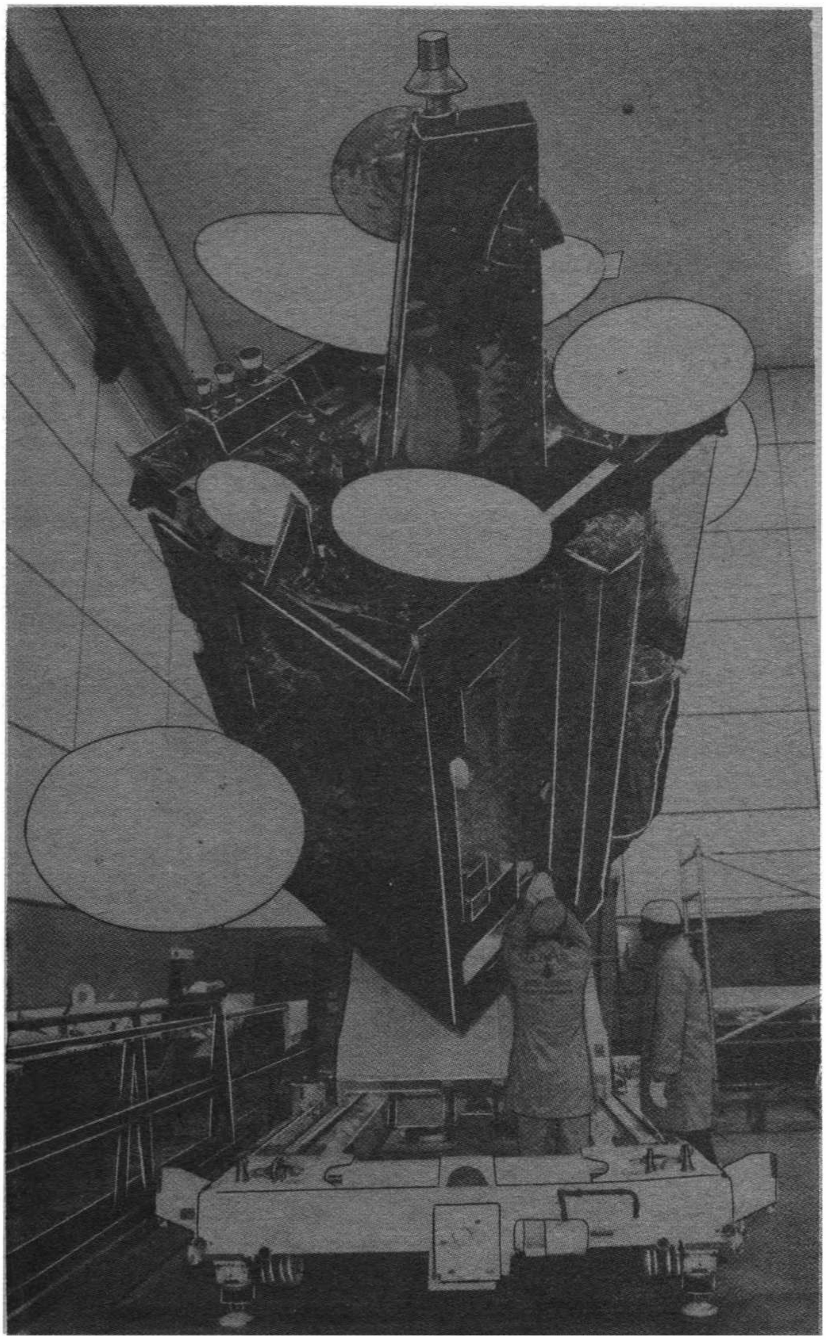
Like its predecessor OTS, the new Olympus satellite offers the potential to develop new services ahead of commercial exploitation.

Olympus represents a new generation of spacecraft which will extend European know-how in a field which has far-reaching international repercussions, with world-wide networks for teleconference, and the use of satellite links for the retrieval and transfer of information. With its powerful direct broadcast beams, Olympus will broadcast direct to millions of home and office antennas.

The Continuing March of Progress

ESA's telecommunication satellite programme continues in order to prepare for the missions of the future. Included in it are up to three experimental satellites which are scheduled for launch in the first half of the next decade, and the development of data relay satellites which will become operational in the second half, in support to the in-orbit infrastructure. According to Ed Ashford, Head of the Communication Satellites Division at ESTEC "the lessons learned in the development operations of OTS, ECS and Marecs have been invaluable in helping to shape the content of these future programmes".

The British Aerospace built Olympus telecommunications satellite is examined by two BAe technicians in an environmentally clean room. *BAe*



BOOK NOTICES

Jane's Spaceflight Directory 1988-89

Ed: R. Turnill, Jane's Defence Data, Sentinel House, 163 Brighton Road, Coulsdon, Surrey, CR3 2NX., 1988, 643pp, £80.00.

Jane's Spaceflight Directory, now in its 4th year of issue, represents what is probably the most exhaustive compilation of space data presented in a ready-to-hand form now available. There are over 500 pictures and more than 1,000 programmes are covered.

After several introductory but most useful chapters, the main bulk of the book thereafter divides into two major sections, of roughly equal length. The first, which amounts to about one half of the book, summarises national space programmes, taking each country alphabetically. The overview thus provided is both comprehensive and informative though many who read the entry under "Britain" will, no doubt, regard this either as a horror story or, at very least, a shambles of the first order. Most readers will draw their own conclusions though a common interpretation might be that it records how various entrenched interests successfully defend their positions on all fronts and shut out every chink of light from a dawning Age of Enlightenment.

The second half of the book is concerned with a variety of topics on various themes e.g. on international space programmes and military space. Sections are included on launchers, space facilities, astronauts and the space industry generally, this last being expanded over the previous edition. Space probes are also included, along with data on the various bodies which make up our Solar System. The Soviet section is fuller by the inclusion of data following the visit of the Editor to the USSR during the year who points out that, although Glasnost in space has not really arrived, US-Soviet collaboration on biosatellite activities has continued over the past fifteen years irrespective of political ups and downs.

Nearly Normal Galaxies

Ed: S.M. Faber, Springer-Verlag GmbH & Co., Postfach 10 51 60, Haberstrabe 7, D-6900 Heidelberg 1, Germany. 1987, 464pp, Hard Cover DM 72.

Subtitled "From the Planck Time to the Present" this book presents some fifty Review talks given in July 1986 as part of a two-week workshop which reviewed the latest research on galaxy formation and evolution.

A unique feature was the treament of galaxy formation from the earliest density fluctuations in the early Universe up to the latest phases of formation and evolution which we see at the present time.

Galaxies are really the basic building blocks of the Universe, the units whereby the large scale structure of the Universe may be recognised. The internal processes which take place within them involve all the fundamental components of astrophysics; so much so that, until recently, this occupied most attention. Now it is recognised that it is also essential to relate galaxies to their environments, for great numbers congregate into large structures which, in turn, influences them individually.

But how did galaxies originate in the first place? Were they the direct descendants of early density irregularities in the big bang? Indeed, and even more intriguing, do we live in a Universe where some unknown but probably large fraction of its mass exists in some unknown form?

The book is divided into sections which examine, in turn, both current theories and observations applied to Stellar Evolution, Small Objects (dwarf galaxies), Galactic structure, Galactic Parameters, the Relation of Galaxies to Larger Structures, Distant Galaxies and Dark Matter.

The Inner Limits of Outer Space

J.C. Baird, Trevor Brown Associates, Suite 7b, 26 Charing Cross Road, London, WC2, England. 1988, 226pp., £14.25.

The author, a psychologist who participated in a 25-strong NASA Study team to explore the feasibility of detecting radio signals from presumed extraterrestrial civilisations, states that he soon discovered, to his dismay, that the engineers, physicists and astronomers in the group settled on a narrow set of conceptions as to what form a message from outer space might take.

This, he regards, as a blind spot which could result in billions of dollars potentially being wasted in implementing a flawed search that might not even be able to recognise an alien message, let alone decipher it. From that point he advocates more involvement by social scientists able to analyse inherent human psychological biases and "whose minds are more open to alternative, though less-proven, modes of communication".

The R.A.E. Table of Earth Satellites 1957-1986

D.G. King-Hele *et al*, Macmillan Publishers Ltd., Distrib. by Globe Book Services Ltd., Canada Road, Byfleet, Surrey, KT14 7JI, England. 1987, 936pp, £95.

Even before the launch of Sputnik 1 on 4th October 1957, scientists at the RAe Farnborough had already made several studies of Earth satellites and their orbits, stemming from earlier work in the 1950's on the Blue Streak and Skylark rockets. Within a few days of launch, Sputnik 1 was regularly tracked by a radio interferometer at an RAE outstation, thus enabling its orbit to be determined and the decay rate used to evaluate a density of the upper atmopshere.

Since then, the RAE has specialised in the analysis of satellite orbits to determine upper atmosphere density and winds, as well as the Earth's gravitational field. In order to choose suitable satellites, a listing was necessary, thus leading, over the years, to the present volume containing data on more than 17,000 satellites, including fragments, in 893 pages of tabulation. Extensive revisions have been made to this, the third edition, to include not only all new launchings to extend the period covered to 1986 but also to incorporate over 1,000 revisions to the earlier data.

A major difficulty, shown clearly in this volume, is the lack of accurate information about the size, shape and weight of most satellites. The reason is that most launchings are of a military nature so that little information is released either about such satellites or their final-stage rockets. The compilers, therefore, have relied largely on deductions from the visual appearance in the night sky and on identifying previous launchings of similar character. By way of contrast, full details appear of most international satellites, particularly those launched by NASA.

New Opportunities for all People

Pergamon Journals Ltd., Headington Hill Hall, Oxford, OX3 OBW. 1987, 399pp.

This, a special volume of "Acta Astronautica" contains selected proceedings from the 37th IAF Congress at Innsbruck, Austria held in October 1986.

As is customary for such Proceedings nowadays, the text has been printed directly from MSS submitted by authors so some unevenness results, particularly in the matter of illustrations, in spite of, doubtless, every effort to ensure that authors adhere to some common practice.

A total of over forty papers are included, chiefly of a survey or state-of-the-art character, so the coverage is substantial. The text falls within five main sections viz Space Systems (including Policy, Utilization, Technology, Operations and Evolution), Space Transportation Systems (including Launchers), Astrodynamics and Space Exploration (including Interstellar Flight), Applications (including Earth observation, communications, microgravity sciences and education) and Technology (including propulsion and energy, structures and navigation) respectively.

The contributions include a considerable amount of "meat" and form a nice blend between present and near-future developments on the one hand, and a perception of where these will lead, on the other.

Interested readers might like to know that the previous volume in this series "Peaceful Space and Global Problems of Mankind" viz Selected proceedings from the 36th IAF Congress in Stockholm, Sweden in 1985 are also available from the same publisher.

Creation: the Story of the Origin and Evolution of the Universe

B. Parker, Plenum Publishing Corporations, 233 Spring Street, New York, NY 10013, U.S.A., 1988, 297pp, $22.95.

This book provides an insight into the violence that rocked the early Universe, as well as the billions of years of gradual evolution which followed and which have left their mark in the stars and elements around us. It is a quite remarkable tale to be told, beginning

with early theories and reaching to the very latest discoveries in cosmology.

The scenario is fascinating and wide-ranging, from happenings in the first few milli-seconds in the life of the Universe up to the role played by galactic objects, today including the enigmatic black holes.

The text is not all about cosmology. Much is about the scientists who contributed the ideas which have led to present concepts of the origin of the Universe.

Exploration of Halley's Comet

Eds: R. Reinhard *et al*, Springer-Verlag, Postfach 105160, Haberstrabe 7, D-6900 Heidelberg 1, Germany, 1988, 984pp, DM 196.

Halley's Comet is both the brightest periodic comet and the most famous of the 750 known comets. Five apparitions ago Edmund Halley discovered the periodicity of the comet and predicted its return in 1758, a remarkable event given the prevailing views on comets at the time. Its most recent return, during 1985/86, was one of the most important apparitions of a comet ever. It provided the worldwide science community with a wealth of exciting new discoveries, the most remarkable of which was undoubtedly the first images of a cometary nucleus.

The 1985/86 appearance began with the record-breaking recovery of the comet on 16th October 1982, while still 11 astronomical units from the Sun. This was 3½ years before perihelion so it was not until late in 1985 that the comet was close enough to the Sun to become fully active.

The combined studies of thousands of scientists around the globe throughout its return generated a huge amount of scientific data which has since undergone preliminary evaluation, with many of the results presented at a special Symposium held in Heidelberg in October 1986. Although the main emphasis then was, of course, on Halley's Comet, papers on other comets were also included in order to show the Halley results in proper perspective. Altogether a total of 370 papers were produced, many of which were published in ESA Special Publications SP-250.

After the Heidelberg meeting, many of the manuscripts were subsequently revised and re-written for publication in a special issue of the *Journal of Astronomy and Astrophysics* (Vol.187 Nos 1–2). The present book reprints all the papers from that issue together with a summary of the scientific results of the Heidelberg Conference and a further five papers which give background information about the various space missions to Halley's Comet and the special International Halley Watch set up to coordinate and maximise data obtained. The latter embraced more than a thousand astronomers from over 50 countries and resulted in an almost-continuous coverage of the comet over a wide range of wavelengths.

The result of all this is a basic reference book which not only embodies a comprehensive account of the current state of scientific knowledge about Halley's Comet but also indicates implications which apply both to other comets and to concepts on the origin and evolution of the Solar System.

The Home Planet

K.W. Kelley, Queen Anne Press, 3rd Floor, Greater London House, Hampstead Road, London, NW1 7QX, England, 1988, £20.00.

Feelings felt and expressed by many of the 200 men and women from 18 nations who have travelled in space and looked down at the Earth beneath are reproduced in this book, together with a 150 of the best photographs selected from Soviet and American Archives. The accompanying narratives are usually deeply personal, attributable to the astronaut involved, and appear both in the language of the publisher and in the native language of the flyer himself.

This is not a book to be read, as such. It is, basically, a selection of pictures of the Earth (and some of the Moon) reproduced side by side with relatively short utterances by those first involved and which reflect the feelings and experiences of awe, wonder and interest evoked by the sights below.

The Universe from your Backyard

D.J. Eicher. Kalmbach Publishing Co., 1027 N. 7th St., Milwaukee, WI 53233, USA. 196pp. 1988. $24.95.

This book provides a guide to finding and enjoying nearly 700 of the sky's finest objects, based on text previously published in *Astronomy* magazine. Included are double and multiple stars, variable stars, open and globular star clusters, bright and dark nebulae, planetary nebulae and galaxies.

The treatment is on a constellation-by-constellation basis, in alphabetical order. The text for every constellation is accompanied by a detailed star map showing the location of each object described, together with illustrations of a number of the more spectacular celestial "sights". Forty-six constellations are treated in this way.

The Supernova Story

L.A. Marshall, Plenum Publishing Corporation, 233 Spring Street, New York, NY 10013, U.S.A., 1988, 296pp, $22.95.

Supernovae represent a phenomenon fundamentally different from that of ordinary novae. Compared to a supernova, an ordinary nova sends out a few faint splutters of light and a few feeble puffs of gas whereas a supernova rends a star to pieces and plays a central role in the formation of elements, the shaping of galaxies and, undoubtedly, in the evolution of life itself.

The dazzling supernova SN 1987A which occurred in the large Magellanic Cloud, 160,000 years ago and which only recently became visible from Earth, provided one of the greatest cosmic events of modern times. This exploding star captured the imagination of scientists and amateurs alike. The brilliance of its display heralded a new era in the study of supernovae which has led to a deeper insight into the origin and complex history of such objects.

The present volume does not, however, relate solely to SN 1987A. It describes observations collected over many centuries, dating from ancient Chinese records to the Middle Ages. The result is an astonishing record of past stellar cataclysms.

Origins

A.C. Fabian, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, England, 1988, 168pp, £12.95.

In this volume a distinguished team of international authorities report on the latest research on the origins of some of the most fundamental features of our world.

The book begins with a bang, the Big Bang in actual fact, that heralded the probable start of our expanding Universe. Other contributors then focus on the origins of the Solar System, material complexity, and human origin and evolution. The volume ends with essays on the origins of social behaviour, society and language.

The Role of the Fine-Scale Magnetic Fields on the Structure of the Solar Atmosphere

E.H. Schroter, M. Vazquez and A.A. Wyller, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU. 1987, 379pp, £35.00.

This volume arose from the inauguration of the international observatories at La Palma and Tenerife in 1985. The inaugural workshop, described in this book, was in the October of the following year. Its major aim was to stimulate discussion between observers and theoreticians on some of the current problems of solar physics. The first group of papers concerns the Sun's atmospheric structure and activity, e.g. the sunspot cycle, beginning with problems of the solar granules and the extent to which these may or may not be modified in regions of solar activity. This is followed by a discussion of the interaction between magnetic fields and convection and a number of contributions on the fine structures e.g. those close to sunspots or faculae. This includes contributions to the sub-surface structure of sunspot, particularly how these active regions originate. An interesting question concerns sunspots themselves. These consist of a dark central area (the umbra) surrounded by lighter area (the penumbra). But *why* this is so? Why should there be a penumbra at all?

A multitude of questions such as this indicate the nature of the work still to be done and suggest scope for future integrated observcational experiments, with all available solar observing facilities put into use simultaneously.

The instruments planned for La Palma and Izana, clearly, represent the highest concentration of solar instruments in the world. The sites are excellent and may be the best available, besides being easily accessible to European astronomers.

All the signs are that the study of the Sun is about to expand into a new phase.

First cadre Manned Space Flight Engineers at Rockwell International, November 1982. Back row, L–R: Sefchek, Rij, Wright, Detroye, Watterson, Higbee, Casserino. Front row, L–R: Vidrine, Payton, Lydon, Joseph, Sundberg, Hamel *All photographs USAF*

The Manned Space Flight Engineer Programme

by Michael Cassutt

From the moment it was approved in April 1972, America's space shuttle was intended to be a "national launch system" replacing all expendable military and civilian launch vehicles by 1980. It is unlikely that the shuttle would have been built without this goal: the famous Mathematica study "proved" that the shuttle would be economical only if it carried all of America's space traffic [1].

Since a majority of America's space launches have been for military purposes, it was inevitable that the shuttle would require the participation of the US Air Force, the official launch agency for not only the military services, but for American intelligence agencies as well.

In exchange for its grumbling support, the Air Force demanded – and got – changes in the design of the vehicle to accommodate its need for improved cross-range and large payloads, among others. For its part, the Air Force was to develop an inertial upper stage and fund the construction of orbiters 105, 106 and 107 [2].

These "blue" shuttles would have been "dedicated" to classified military missions launched (in some cases) into polar orbits from the re-designed space launch complex six at Vandenberg Air Force Base, flown by crews of military astronauts, and controlled from a custom-built DoD mission control – the Shuttle operations and Planning Center – which would be part of a new complex called the Consolidated Space Operations Center.

The Shuttle was the Air Force's third attempt at a manned space programme following the X-20 (1963-64) and the Manned Orbiting Laboratory (1965-69), both of which had been cancelled before flying.

However, the decision to "buy into" the shuttle never had total support from all elements of the Air Force, and by the late 1970's, with inflation and a Democratic administration eroding DoD budgets, what Air Force affection there was for the programme began to fade.

The new mission control centre, SOPC, was delayed in favour of modifications to the NASA Johnson Space Center and the three additional orbiters were not purchased – a brief attempt to dedicate OV-103 "Discovery" to the DoD failed. Nor would there be a special corps of "blue shuttle" astronauts. Military officers would have to be detailed to NASA as career astronauts in order to fly as pilots or mission specialists.

The only opportunity for an Air Force programme seemed to be in NASA's new class of "payload specialists," non-career astronauts whose training would centre on payloads, not the shuttle itself.

And so in January 1979, Air Force Under-secretary Hans Mark created a cadre of military payload specialists – people who could explain the Air Force to NASA while explaining the shuttle to the Air Force [3]. A military designation was coined: manned spaceflight engineers.

Even though the DoD would ultimately select senior Air Force officials, US Navy oceanographers and Air Weather Service officers as shuttle payload specialists, MSEs would be the first personnel from an American military programme to go into space.

This article traces the history of the Manned Spaceflight Engineer programme, based on interviews, press reports, published books, and official Air Force documents.

The First Cadre

Initial responsbility for the definition of the pilot MSE programme fell to Lt. Colonel Robert E. Christian III at Los Angeles Space Division, and his deputy, Capt. Gregory Gillis, both of whom had extensive experience in military space programmes. Christian had also been an Air Force representative at presentations made by Rockwell International concerning manned space programmes as early as 1969.

Among their many tasks was the requirement that the MSE be a "tri-service" programme creating a cadre of Air Force, Navy and Army personnel experienced in shuttle operations and the special requirements of military payloads. It was hoped that after tours of duty lasting from four to six years and following flights aboard the shuttle these officers would return to "normal" careers and eventually rise to command positions in the services' growing space programmes.

Selected organisations in the USAF, Navy and Army were briefed on the pilot programme. Requirements were drawn up and applications were solicited from qualified personnel. The first MSE candidates were required to:

- Have at least three to ten years' service as an officer on active duty.
- Rank from first lieutenant to major.
- Be able to pass a NASA Class III flight physical.
- Be holder of a bachelor of science degree in engineering, science or space operations, with a master of science in those areas desired.
- Have a minimum of two years' experience in programme acquisition, test and launch support, of flight and missile operations [4].

Flying backgrounds were not required, though pilot applicants had to have met their first "gates" (minimum requirements for flying time). In addition, of course, applicants had to hold the appropriate security clearance.

In August 1979, fourteen officers, 12 Air force and two Navy, were selected. One Air Force officer, Maj. Carl Hatlelid, declined the appointment and was replaced by an alternate, Capt. Gary Payton; Navy Lt. Commander Paul Schlein also declined and was not replaced, leaving 13, who reported to the Air Force Space Division in El Segundo, California, to begin initial training in February 1980 under the direction of Lt. Col. Christian. The officers were:

1Lt. Frank J. Casserino, (24), USAF
1Lt. Jeffrey E. Detroye, (25), USAF
Capt. Michael A. Hamel, (29), USAF
Capt. Terry A. Higbee, (30), USAF
Capt. Daryl J. Joseph, (30), USAF
Maj. Malcolm W. Lydon, (33), USAF
Capt. Gary E. Payton, (31), USAF
Capt. Jerry J. Rij, (30), USAF
Maj. Paul A. Sefchek, (33), USAF
Maj. Eric E. Sundberg, (34), USAF
Lt. Cmdr. David M. Vidrine, (36), USN
Capt. Keith C. Wright, (32), USAF
Capt. John B. Watterson, (30), USAF

The initial requirements were intended to recruit a cadre of military space professionals, and in that they succeeded. Vidrine was an engineer with the US Navy Space Project. Higbee, Joseph, Rij, Sefchek, Sundberg, Wright and Watterson were already working on various programmes at Space Division. Payton, the alternate selectee, had been a launch controller at Cape Canaveral in addition to being one of two flight-rated members of the group. Casserino and Detroye had only recently arrived at Space Division from the Satellite Control Facility at Sunnyvale, where they, like Lydon, had been satellite controllers and engineers.

Casserino and Detroye had less than three years as officers at the time of selection; Vidrine had served for 15. Detroye was the only MSE without a master's degree, though he had done graduate work.

Thus the MSE programme began, with high hopes and great expectations. Maj. Gen. John E. Kulpa, Jr., deputy commander for space operations (DCSO) of the Space Division and one of the programme's biggest supporters, welcomed the men with a speech calling them the "future of the Air Force in space".

But problems surfaced even during the first weeks of training. In addition to valuable exposure to shuttle systems at Rockwell International's flight systems laboratory in nearby Downey, California, the original programme relied heavily on a schedule of monthly, week-long visits by the 13 MSEs to various military satellite contractors. This proved to be unworkable and the contractor visits were reduced in favour of vists to other Air Force installations as well as the NASA Johnson and Marshall Space Centers [4].

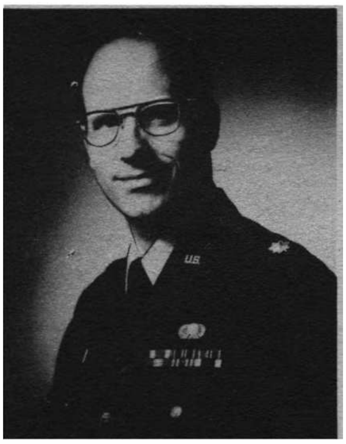
There were also immediate conflicts with NASA officials, in part because NASA had yet to define its own payload specialist training programme.

Early in the MSE programme, the civilian agency had suggested to the Air Force that it would be happy to accept the MSEs at the Johnson Space Center for two years of training, which is just what the Air Force did not want. In the words of one officer: "At that time any Air Force guy who went to NASA never came back!"

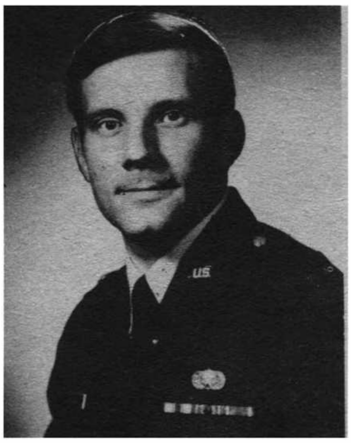
When the Air Force declined the offer, NASA refused assistance of any kind, taking the position that it had not selected and therefore could not control the MSEs [5]. As late as 1983 one NASA official wrote that he considered MSEs to be engineers and not "flyers", and that they should not partake in any flight training activities until selected as actual payload specialists [6].

Ironically, some MSEs and their managers found themselves frustrated by NASA's excessively-rigid insistence on secrecy. Differences in managerial style and control over flight issues escalated to the point where the more aggressive MSEs found themselves unwelcome at the Johnson Space Center, whose director, Christopher Kraft, was called upon to referee at least one dispute.

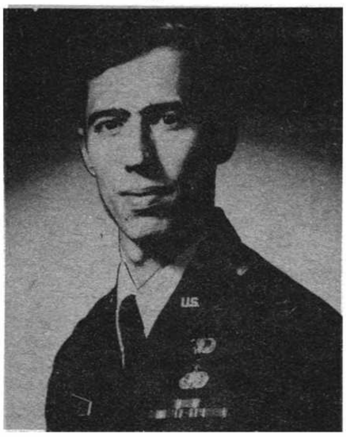
James Armor



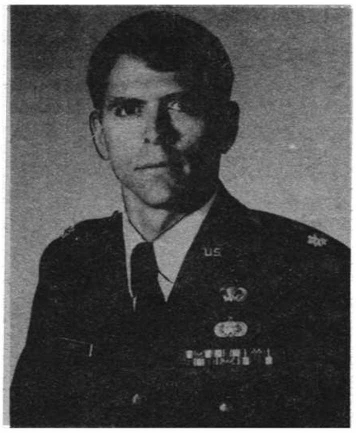
Michael Booen



Livingstone Holder



Larry James



Charles Jones

Maureen LaComb

Nevertheless, during the first months of training, members of the first cadre of MSEs had great expectations, having been told that each of them could anticipate flying in space at least once and several of them twice [7]. They took part in underwater EVA and manned manoeuvring unit simulations at NASA Marshall and Martin Marietta, respectively, and went through shuttle mission simulations at Rockwell. Ultimately some members of the group even rode in T-38 jets at Edwards Air Force Base. Such experience gave MSEs greater familiarity with shuttle systems and operations than any other payload specialists and, indeed, many NASA flight controllers [8].

In early 1980 the officers had also been assigned to different Space Division system project offices (SPOs) to become intimately familiar with the multitude of military payloads: the Space Test Programme of scientific experiments, the General Electric Defense Satellite Communications System, the Rockwell Navstar Global Positioning System, and especially classified systems – commonly known as Special Projects – developed by TRW, Hughes, Martin Marietta and Lockheed under the direction of the highly-secret National Reconnaissance Office [9].

In December 1981, the first cadre of MSEs completed training and the experimental programme was officially recognised as the Directorate for Manned Spacecraft Support, Space Division.

Lt. Col. Christian retired from the Air Force in October 1981 and was replaced by Lt. Col. David Richardson, who served until the spring of 1983, when Lt. Col. Thomas Redmond became Director, Manned Spaceflight Support. Redmond was replaced in November of that year by the ranking MSE, Cmdr. David Vidrine.

Second Cadre

By the summer of 1982, it was obvious that more MSEs were needed if the programme was to be adequately represented in Space Division SPOs. Requirements for the second cadre were similar to those of the first, except that this time only USAF officers were to be considered. Announcements were circulated to personnel offices and published in the *Air Force Times* soliciting applications from officers eager "... to help change military space experiments that now are designed to be controlled from the ground to ones that can be directly manipulated by astronauts in orbit" [10].

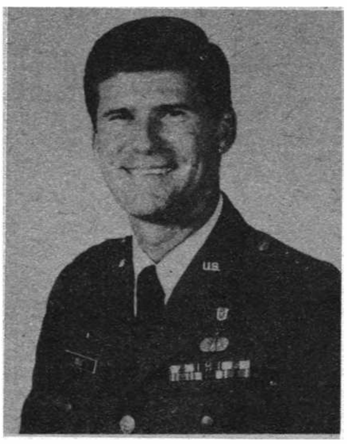
From 66 finalists, 14 officers were selected in August 1982, to report to Space Division in January 1983:

Capt. James B. Armor, Jr. (32)
1Lt. Michael W. Booen (25)
Capt. Livingston L. Holder, Jr. (27)
Capt. Larry D. James (27)
Capt. Charles E. Jones (30)
1Lt. Maureen C. LaComb (26)
Capt. Michael R. Mantz (28)
Capt. Randy T. Odle (31)
Capt. William A. Pailes (30)
Capt. Craig A. Puz (28)
Capt. Katherine E. Roberts (28)
Capt. Jess M. Sponable (32)
Capt. W. David Thompson (26)
Capt. Glenn Scott Yeakel (26)

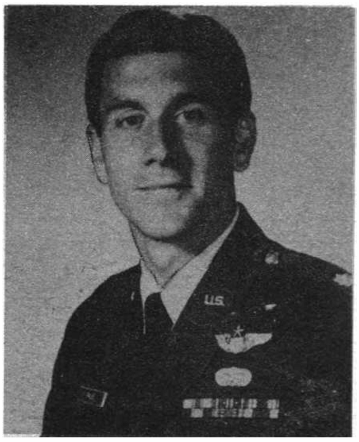
The second cadre included two women (Roberts and LaComb) and a black officer (Holder). Backgrounds of the officers, unlike those of the first cadre, did not emphasize space engineering and operations. Odle, for example, had been a bio-environmental researcher at RAF Alconbury in the UK; LaComb and Mantz were primarily computer specialists. Pailes was a rescue pilot now working on microcomputer systems. Puz and Armor had been commanders of Minuteman

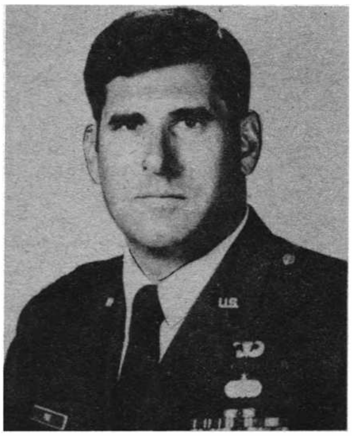
Michael Mantz

Randy Odle



William Pailes




Craig Puz


Katherine Roberts


Jess Sponable

missile crews. Booen was a weapons engineer.

Several of those who had worked on space projects had only two or three years' experience and they were also, on the average, younger than the first cadre. More significantly, the new selectees were told that only half of them might fly in space. It was as if the first cadre were pathfinders – pioneers – and the second cadre were homesteaders.

Training for the 14 new officers was similar to that of the first 13, though more organised, and "graduation" took place in January 1984, when they, too, were assigned to Space Division SPOs.

During 1984 there was some attrition: Commander Vidrine retired in October and one officer was dropped from the programme.

Assignments

MSEs gained their first mission experience working with astronauts T. K. Mattingly and Henry Hartsfield, the crew of STS-4, the last shuttle orbital test flight, which carried the P-80-1 experiment package. MSEs Sefchek and Watterson worked on the payload while Casserino, Detroye and Payton acted as "paycoms" (payload communicators) at the Air Force Satellite Control Facility in Sunnyvale, California. The best known of the "secret" experiments, a sensor known as CIRRUS, failed to operate as planned [11].

Just prior to STS-4, in June 1982 the first payload specialist selection board named seven MSEs as prime or backup candidates for three different shuttle missions scheduled for 1983 and 1984: STS-10 (Payton/Wright), STS-15 (Detroye/Sundberg/Watterson) and STS-16 (Casserino/Joseph). Reported payloads included a TRW/Defense Support Programme early warning satellite as well as two intelligence satellites, some of which were designed to be boosted into geosynchronous orbit by the Boeing inertial upper stage following release from the shuttle. The military payload specialists would observe satellite deployments and IUS firings, and operate scientific experiments [12].

Delays

On April 4, 1983 during deployment of the first Tracking and Data Relay Satellite from STS-6, the IUS suffered a failure which had serious repercussions on the MSE programme, forcing massive changes in the military payload manifest: STS-10 was immediately cancelled, followed in February 1984 by STS-15 (then designated Mission 41-E) and in April 1984 by STS-16 (Mission 41-H).

In fact, the STS-10 payload, widely reported to be a TRW/National Security Agency ELINT satellite called Magnum, was configured only for shuttle launch with IUS and could not be cancelled – it had to be slipped from one shuttle IUS slot to another.

Published reports have stated that the original STS-15/Mission 41E and STS-16/Mission 41H payloads were dualconfigured for shuttle or Titan and simply shifted from one system to the other – the 15/41E for a January 1984 Titan, the 16/41H to one launched in December 1984 [13]. Other sources indicate, however, that 15/41E was simply cancelled while 16/41H was postponed indefinitely.

In any case, because of Magnum's importance, the DoD exercised its "launch on demand" option, preempting the next shuttle/IUS spot on the manifest, Mission 51C, which was intended to launch the civilian TDRS-B. TDRS-B was moved to Mission 51E.

The second MSE selection board, in the summer of 1983, confirmed the assignment of Maj. Gary Payton as prime PS and Maj. Keith Wright as bac-


David Thompson


Scott Yaekel


Joseph Carretto

kup PS for what was then STS-15. It also named Capt. Frank Casserino as prime PS with Maj. Daryl Joseph as backup for STS-16.

At this time there was a brief and unsuccessful attempt to place MSEs on "civilian" shuttle missions for which DoD was contributing funds. Commander Vidrine became a candidate for PS "observer" on STS-13/Mission 41C, the Solar Maximum Mission rescue, and even went through flight simulations with the astronaut crew commanned by Capt. Robert L. Crippen (USN).

In March 1984, however, one month before scheduled launch, Maj. Gen. Kulpa's successor as Space Division DCSO, Maj. Gen. Ralph G. Jacobson, refused to authorise Vidrine's flight, claiming it had "no value" to the Air Force, and pulled him from the crew.

A year earlier, in March 1983, Jacobson had summoned Christian and the first cadre MSEs to his office for what came to be known as "the Saturday Morning Massacre". Jacobson was concerned about shuttle launch delays and wanted the MSEs to understand that his mission, i.e., the launch of national security payloads, dwarfed their mission, flights in space by Air Force personnel.

It should be noted that the DoD always intended to choose shuttle payload specialists from other services and commands. Civilian Navy oceanographers Paul Scully-Power and Robert Stevenson were selected in early 1984; Scully-Power went into space that October aboard Mission 41G in place of Stevenson, the original first choice. Stevenson was re-manifested for a series of shuttle missions beginning with STS-15 and was finally assigned to Mission 61K, scheduled for 1986, only to see it cancelled following the "Challenger" disaster.

In late 1985 three officers from the Air Weather Service were selected for another 1986 shuttle flight, the Weather Officer in Space Experiment (WOSE). The Navy also intended to fly a command, control and communications specialist in 1987. These were in addition to MSE and "dignitary" payload specialists such as Air Force Undersecretary Edward Aldridge and Gen. Lawrence Skantze of the USAF Systems Command.

Conflict

The Vidrine incident was just one sign of the continuing struggle within the Air Force over the value of the shuttle versus expendable launch vehicles. Hans Mark and Maj. Gen. Kulpa had championed military man-in-space activities, but their successors, notably Edward "Pete" Aldridge, were doubtful that the shuttle would ever be reliable enough for operational military needs [14]. Aldridge successfully fought for the purchase of 10 additional Titan expendable launch vehicles in 1985 and saw his judgement vindicated when the shuttle "Challenger" exploded, grounding the programme for a lengthy spell.

Even among Air Force space proponents, opinion on the shuttle was sharply divided. Some officers had a clear vision of its usefulness for military activities while others scorned it as a fragile research vehicle. The shuttle also suffered from the "not invented here" stigma [15].

The MSE programme provided a focus for this debate, becoming, in the words of one MSE, "grist". Some senior Space Division officers supported the programme while others did not. Cadre commanders, notably Col. Mart H. Bushnell (who succeeded Vidrine in 1984), lobbied unsuccessfully for additional officers and for SD support with NASA, which had the already noted reservations about the MSEs [16].

In 1983 there was an attempt to give the MSE programme more clout inside the Air Force and NASA with a single stroke when Space Division officials asked astronaut John Fabian, a USAF colonel detached to NASA and veteran of STS-7, if he would consider returning to Space Division to head the group, but Fabian declined [17].

The low point of MSE morale was probably the last months of 1984. In October, the third selection board named Maj. Brett Watterson and Capt. Randy Odle as prime payload specialists and Capt. Michael Mantz as backup for shuttle Mission 62A, the first Vandenberg-launched orbital flight test. Also named were Capts. William Pailes (prime) and Michael Booen (backup) for another DoD launch-on-need payload scheduled to be launched in the autumn of 1985. But no one knew for certain just when these missions would be flown. The Payton/Wright and Casserino/Joseph teams were still on the ground and at least three other payload specialist slots had been permanently lost. Selection of eight or nine new officers for a 1985 third cadre was halted.

Worse yet, Air Force Secretary Vernbe Orr issued a policy statement designed to eliminate "homesteading" – that is, USAF officers should spend no more than four years at one particular station. Officers remaining in one place for greater lengths of time would be penalised when promotions were made.

By this time, of course, all MSEs had been at Space Division for at least four years. Some officers, like Watterson and Sefchek, had spent as many as eight years at SD. Those MSEs without flight assignments immediately made plans to look for other work, and by the summer of 1985, all but Watterson, Casserino and Sefchek had transferred.

Finally, on January 24, 1985, MSE Gary Payton went into space aboard the Discovery on Mission 51C. Nine months later, second cadre MSE Pailes was aboard the first flight of the shuttle Atlantis on Mission 51J.

Just three weeks prior to 51J, in September 1985, Space Division announced publicly that MSE Watterson would fly aboard shuttle mission 62A, the first manned launch from Vandenberg AFB [18]. This was a break in procedure, since Payton and Pailes had

Rob Crombie

Frank DeArmond

(Above) The crew of the first DoD dedicated shuttle mission, STS 51-C. (Kneeling right) Thomas Mattingly, commander, and (kneeling left) Loren Shriver, pilot. (standing left to right) Gary Payton, Manned Space Flight Engineer, James Buchli and Ellison Onizuka, mission specialists.

(Below) The crew that never flew. Mission STS 62-A was to have been the first shuttle flight from Vandenberg Air Force Base. The flight was cancelled following the Challenger Accident. (Front row, left to right) pilot Guy Gardner and mission specialists Richard Mullane, Jerry Ross and Dale Gardner. (Back row left to right) Air Force Undersecretary Edward Aldridge, commander Robert Crippen and Manned Space Flight Engineer Brett Watterson.


MATTINGLY
SHRIVER
ONIZUKA
BUCHLI
PAYTON

only been identified at launch-minus-30 days [19].

The week after Pailes' flight, on October 9, 1985, SD finally disclosed the names of the remaining "active" MSEs:

Capt. Michael Booen
Capt. Larry James
Maj. Charles Jones
Capt. Maureen LaComb
Capt. Michael Mantz
Capt. Randy Odle
Capt. William Pailes
Capt. Craig Puz
Capt. Glenn Yeakel

This list does not include Lt. Col. Payton or Maj. Watterson, who had been publicly identified, or Capt. Casserino, who had not, because these officers were still assigned to Special Projects. They were not formally associated with the MSE programme, though they remained eligible for assignment to shuttle crews. Second cadre officers Armor, Holder, Roberts and Thompson were also assigned to SP.

The question of publicity in itself mirrors the debate over the value of the MSE programme. Officers selected for the first cadre in 1979 were, in some cases, identified through the Pentagon's hometown press service and not instructed to keep their new assignment secret. Maj. Payton's biography, identifying him as a manned spaceflight engineer, was published in Janes' *Who's Who in Aerospace and Aviation* in 1984. The new MSEs were under the impression that the Air Force, as it had with the X-20 and MOL pilots, was going to publicise their existence. "An announcement was to be made 'any day now'", one of them says, "but that day never came". Apparently some men sent out the news with their Christmas cards in December 1979, only to be told to recall them.

Existence of the group (which was originally organised as a Special Project) remained secret, by and large, until late 1982, when various publications ranging from the *Houston Post* to *Aviation Week* disclosed the fact that a "secret cadre" of 13 officers was training as shuttle payload specialists.

The *Aviation Week* story appeared as NASA named an astronaut crew commanded by Navy Capt. T.K. Mattingly to STS-10, then scheduled for launch in November 1983. MSEs Payton and Wright also began to train with astronauts Mattingly, Shriver, Onizuka and Buchli, a fact which was surely known to hundreds of civilian employees of the NASA Johnson Space Center.

MSE Pailes, who found himself frozen out of certain crew functions and forced to invent cover stories to explain his presence at JSC, would later propose a change in security policies to allow for disclosure of the MSE at the same time the NASA crew was announced [20].

In May 1983 Space Division issued a press release confirming the existence of the MSE group and stating that 27 officers had been trained. It was rumoured that SD was now willing to provide pictures and biographies of the MSEs, but, again, no release was made and queries were met with silence (MSE biographies eventually obtained by the author some years later were all dated May 1983).

One MSE suggests that publicity for the group would have implied a greater level of Air Force support for the programme than actually existed. In any case, it was not until reports appeared in the press concerning the Pentagon's secret cadre of "soldier-astronauts" [21] that official clarifications were made.

By November 1985, experience with two successful DoD-dedicated shuttle missions had allowed the Air Force and NASA to reach mutual agreement on dealings concerning security, manifesting and other issues. In addition to the oft-delayed Vandenberg Orbital Flight Test, Mission 62A, five other dedicated missions were scheduled to be flown up to May 1987. The first two launches of Navstar GPS satellites were also scheduled. The fourth MSE selection board met that month and assigned five officers as prime payload specialists for the six new flights: Casserino, James, Jones, Roberts and Puz. Capt. Larry James would make two flights with Navstar. Plans for the selection of a third cadre, cancelled in 1984, went ahead. It appeared that the MSE programme was about to be vindicated.

Then, on January 28, 1986, the shuttle "Challenger" exploded during launch.

Aftermath and The Third Cadre

During the spring of 1986, as the American space programme suffered through a seige of failures and reappraisal, Air Force space managers decreed that MSEs would no longer accompany certain payloads on shuttle launches. This list included TRW Defense Support Program satellites in addition to the previously-mentioned DSCS and Navstar GPS payloads. The primary reason cited was concern for safety. MSEs would continue to train for flights with selected national security payloads, with the Strategic Defense Initiative's "Starlab" (variously known as the Tracking and Pointing Exercise or TPE, PATIE, and Blue Spacelab) and with DoD scientific experiment packages.

Col. Bushnell was reassigned in March and succeeded as Director of Manned Spaceflight Support by Lt. Col. Pailes, the ranking MSE. The five members of the third cadre arrived on April 30, 1986, to begin their initial training. They had been selected from over 500 applicants the previous August:

Capt. Joseph J. Caretto (29)
Capt. Robert B. Crombie (32)
Capt. Frank M. DeArmond (31)
Capt. David P. Staib, Jr. (30)
1Lt. Teresa M. Stevens (25)

Four of the new officers had operational space backgrounds – Caretto and Stevens had worked as shuttle flight controllers with the 1st Manned Spaceflight Support Group at the NASA Johnson Space Center while Staib had been an IUS controller at Cape Canaveral and DeArmond a satellite control officer at Sunnyvale. Crombie was a flight test engineer. They completed training in January 1987.

The revised shuttle programme manifest issued in late 1986 called for five dedicated DoD missions in the first year of resumed operations, presumably providing opportunities for flights by several MSEs. Yet just four weeks later, NASA Administrator James Fletcher announced that the first five shuttle missions, including two DoD flights, would be flown by five-member NASA astronaut crews only. Fletcher further expressed the desire to keep PSs of all kinds off shuttle flights

David Staib

Theresa Stevens

The crew of the second DoD dedicated shuttle mission STS 51–J. (Front centre) Karol Bobko, commander, (front right) Ron Grabe, pilot, (rear left) William Pailes, Manned Space Flight Engineer, (rear right) David Hilmers and (front left) Robert Stewart, mission specialists. *NASA*

for the next 20 missions, "... if not forever" [22]. At the same time, the NASA astronaut office was lobbying for the elimination of payload specialists, with the possible exception of Spacelab-type missions, on which a single PS would be included.

Nevertheless, in April 1987 a new payload specialist selection board named Maj. Craig Puz and Capt. Maureen LaComb as prime payload specialists for the StarLab mission scheduled for 1989 or 1990, a decision which was announced publicly in October. Later in 1987 Space Division finalised plans to send two MSEs into space with a payload consisting of the long-delayed AFP 888 Teal Ruby satellite, the AFP 675 Cirrus 1A package, and the Infrared Background Signature Survey (IBSS) camera.

The Future

In spite of the existence of a handful of flight opportunities, by the end of 1987 the MSE programme had been allowed to wither. Cadre director Pailes returned to operational flying as a rescue pilot at Eglin AFB, Florida, and was not replaced. Following the additional transfers of MSEs Booen, Jones, Mantz and Roberts to other Air Force assignments, and resignations by MSEs assigned to Special Projects, the group consisted of ten officers. No further selections were planned.

And it is far from certain that members of the existing group will go into space even on the Starlab or IBSS missions. For example, the SDI organisation plans to assign its own personnel as Starlab backup payload specialists. Further, in late 1987 the US Air Force conducted a new study of "military man-in-space", intended "to settle a 25-year Defense Dept. debate about the relative usefulness of manned versus unmanned systems..." [23]. Of the 11 scheduled "exercises", a majority would require flights by personnel from the Air Weather Service, the US Navy and the US Army, not the MSE group at Space Division, even though MSEs were to integrate the tests. One official speculates that, ultimately, "Payton and Pailes will be the only MSEs to fly".

Acknowledgements

The author wishes to acknowledge the assistance of the former and current members of the MSE programme who took the time to review and correct certain portions of this paper. Any remaining errors are the author's. It should be noted that information concerning military shuttle payloads comes from open literature identified in the notes.

References

1 For an analysis of the original shuttle design and goals and the Mathematica study, see *Enterprise* by Jerry Grey (New York Wm Morrow & Co , 1979), pages 72 through 79 in particular

2 For a discussion of the relationship between NASA and the Air Force, see *Prescription for Disaster* by Joseph Trento with Susan Trento (New York Crown, 1986), p 122-149

3 Mark, a former (and future) NASA official, was one of the Air Force's few shuttle supporters. As Undersecretary of the Air Force he was responsible for all military space programmes, including secret "Special Projects" in his "black hat" role as head of the National Reconnaissance Office

4. For a more detailed description of the MSE program and training, see *Spacefarers of the Eighties and Nineties* by Alcestis Oberg (New York Columbia University Press, 1985)

5 NASA Official Jay Honeycutt did advise the MSE selection board

6. Memorandum from Gerald D Griffin, Director National Space Transporation Systems Programme Office, NASA, to Manager, NSTS, August 22, 1983

7 The March 1982 NASA Space Transportation System manifest baseline predicted eleven dedicated DoD missions between June 1982 and September 1985

8 From time to time, USAF space managers considered the idea that manned spaceflight engineer training should be prerequisite for all Air Force mission specialist astronaut candidates This idea never received strong support, but several MSEs have been submitted to NASA as potential astronauts James Armor, Daryl Joseph, William Pailes, and Gary Payton were nominated in 1985, Pailes and Maureen LaComb in 1986 (the suspended selection) and again in 1987 Pailes was a finalist for the 1987 mission specialist group.

9 For a description of US military satellite programmes, see *Deep Black* by William Burrows (New York Random House, 1986) and *Guide to Military Space Programmes* by C Richard Whelan (Arlington, Va Pasha Publications, 1984)

10 *Air Force Times* "Officers Needed to Redesign Space 'Control' Experiments," May 24, 1982

11 For a description of the STS-4 payload, see *Aviation Week*, June 4, 1982

12 It has been rumoured incorrectly that some MSEs would have performed EVA. While it is true that members of the group were trained in EVA procedures, including use of the manned manoeuvring unit, US Code presently allows EVAs only by NASA mission specialists and pilots

13 *Aviation Week*, February 13, 1984 See also Anthony Kenden, "US Military Activities in Space – 1984", privately published, 1985

14 See Trento, p 234-235

15 There was a virtual repeat of the Vidrine incident later in 1984, when NASA offered Space Division the opportunity to add a second payload specialist to the crew of Mission 51C SD officials declined

16 In early 1985 SD officials requested a seat for a payload specialist MSE (Capt Scott Yeakel) on Shuttle Mission 51G, then scheduled for June of that year, to operate the MARC-DN camera NASA refused, claiming that payload specialists with "higher priority" were already manifested This elicited a stinging response from SD, since one of PSs was Saudi Prince Sultan Salman al-Saud, a professional broadcaster whose function was strictly that of an observer The issue became moot when other payload manifesting problems delayed the flight of the MARC-DN to Mission 51J, a dedicated DoD flight, where it was operated by MSE William Pailes

17 Ironically, when Fabian finally left NASA in January 1986 he became director of space for the Air Force at the Pentagon, where he supervised the development of military satellites. Trento, p.6, claims this was a Special Projects (National Reconnaissance Office) job, but Fabian reported to the director of research and development, not space systems and C3 The latter job is in the usual NRO chain of command

18 Watterson's fellow payload specialist was to be none other than Air Force Undersecretary Pete Aldridge, Hans Mark's successor, who had assigned himself to the crew, bumping MSE Captain Randy Odle As early as 1983, General Lawrence Skantze, commander of the Air Force Systems Command, had also requested a flight aboard the shuttle and was in the process of being manifested for a 1986 shuttle flight at the time of the "Challenger" disaster

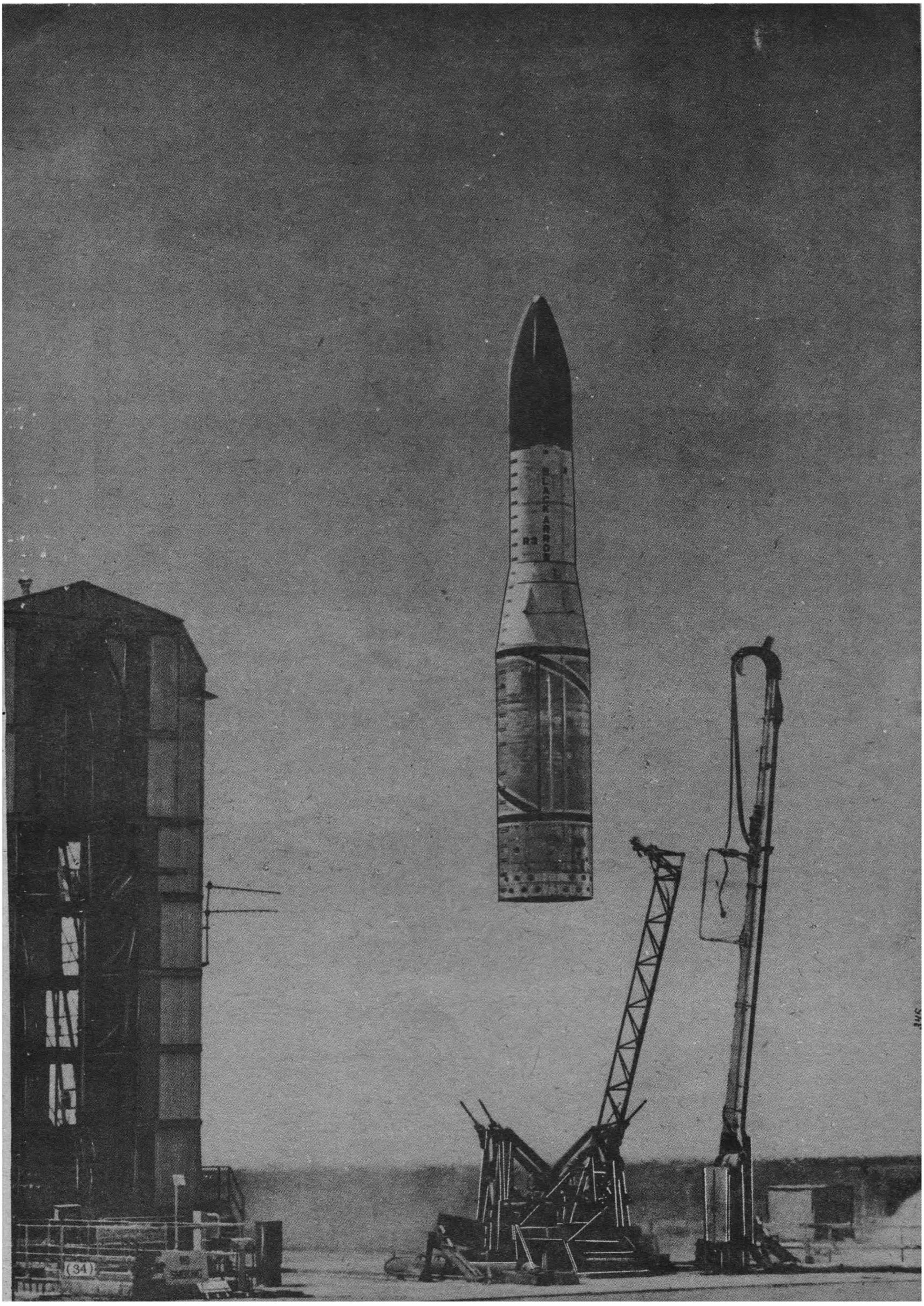
19 Craig Covault, "Military to Withhold Shuttle Lift-off Time", *Aviation Week*, November 9, 1984, p 14 This article also discusses security procedures for military shuttle missions and the "classification" of the Mission 51C crew patch because it contained Payton's name.

20 "51J Postflight Report Some Lessons Learned", William Pailes, October 1985

21 For example, "Space-War Era: It's Already Here", *US News and World Report*, December 17, 1984, p.28

22. Quoted in *USA Today*, January 29, 1987

23. Craig Covault, "USAF Plans Military Exercises on Space Shuttle", *Aviation Week*, January 4, 1988


BLACK ARROW
R3
(34)

Prospero Picture Found

In Correspondence, June 1988, Geoffrey Bowman wrote about his unsuccessful attempts to locate a true photograph of the launch of Britain's first satellite Prospero. Michael Crowe a *Spaceflight* reader in Australia has obtained a copy of the illusive photograph which we have reproduced here in full colour.

Geoffrey Bowman's original letter:

Sir, Following the launch of "Prospero", the first and only all-British satellite, on October 28, 1971, I made numerous efforts to obtain a photograph of the event. I contacted various contractors and government departments without success. They all apologised for being unable to supply "Prospero" launch photographs, and instead sent me numerous photographs showing the unsuccessful Black Arrow launch in September 1970.

On at least two occasions, ***Spaceflight*** has published photographs purporting to show the "Prospero" launch (January 1972, front cover; and April 1986, p.158). In each case the lighting angles and shadows clearly show that photographs of the September 1970 launch have been used. This confusion may have arisen because the 1970 photographs appear to have been issued to the press in anticipation of the launch of "Prospero." One copy in my possession is clearly labelled: "Britain's Black Arrow will launch Prospero from Woomera, Australia."

It would therefore surprise me if ***Spaceflight*** readers (myself included) have ever seen a photograph of Britian's one and only satellite launch, which seems most ironic. Can you now remedy matters, albeit 16 years after the event? If the Society can trace a genuine "Prospero" launch photograph, it surely deserves pride of place in a future issue of ***Spaceflight***.

GEOFFREY BOWMAN
Belfast N. Ireland

Michael Crowe answers Mr Bowman's request:

Sir, As requested by Geoffery Bowman (***Spaceflight***, June 1988, p.527) I have traced a 'genuine' Prospero launch photograph (Negative No:CN71/159).

The lettering on the side of the rocket positively identifies it as being the R3 Black Arrow launch vehicle that placed Prospero, Britain's one and only satellite, into orbit [1].

Without such means of identification one would need to employ the same kind of detective work that Geoffrey Bowman did in trying to distinguish one Black Arrow launch from another.

To lend some credence to his careful scrutiny of the 'Prospero' photographs ***Spaceflight*** has published, (January 1972 and April 1986, p. 158), compare the photograph of the R2 launch with that of the R3. Without the lettering they would be very difficult to distinguish.

In fact, after examining some of the other 'Prospero' launch photographs that have been published [2,3] – incredible though it may be – it seems that all were probably of the R2 Black Arrow launch!

Like the now 'famous' Armstrong-on-the-Moon photograph (***Spaceflight***, December 1987, p. 428 and July 1988 p. 284–285) has the Correspondence page cleared up another historic oversight?

May I conclude by thanking Frank Chapman of the Still Photography Section, Defence Science & Technology Organisation, South Australia, for kindly providing me with these photographs.

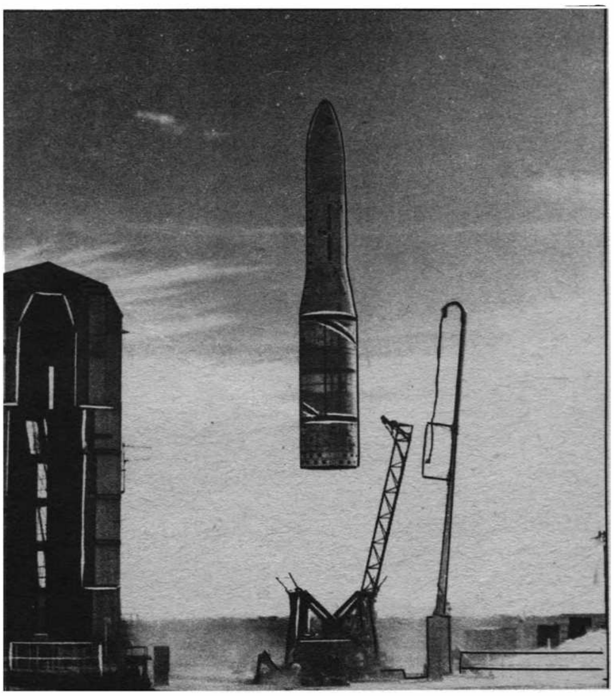
MICHAEL A. CROWE
Waramanga, Australia

References

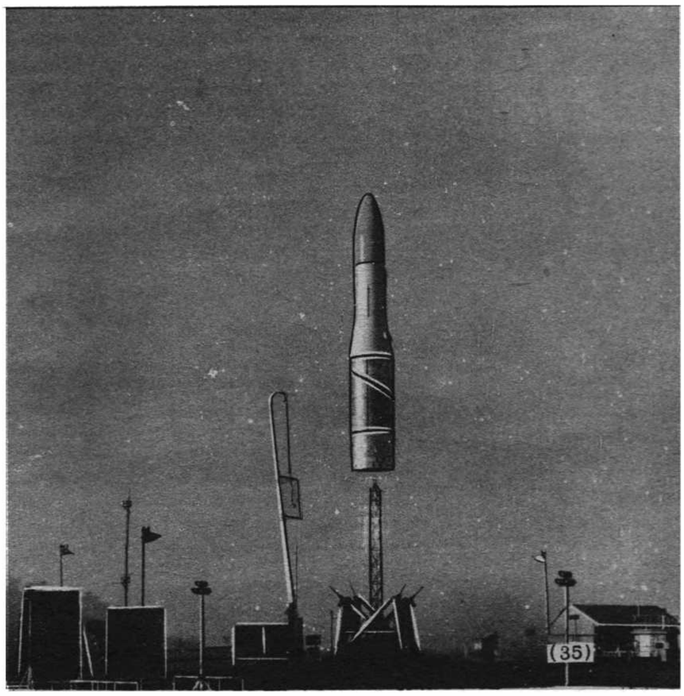
1 *1971–1972 Annual Report*, Weapons Research Establishment, Salisbury, South Australia Australian Government Publishing Service, Canberra 1972, p 23–24
2 *Jane's Spaceflight Directory*, 1984 p 28
3 *Observing Earth Satellites*, D King-Hele, Macmillan, London 1983, p 8

◄The genuine Prospero launch photograph. The Black Arrow R3 launches Britain's first satellite.

The launch of the Black Arrow R2 vehicle.



The R1 lift-off in March 1970.



February 1989 US $3.25 £1.25

Spaceflight

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Spaceflight

The International Magazine of Space and Astronautics

Vol. 31 No. 2 February 1989

Spaceflight Office:
27/29 South Lambeth Road,
London, SW8 1SZ, England

Tel: 01–735 3160.
Fax: 01–820 1504.

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Spaceflight may be received worldwide by mail through membership of the British Interplanetary Society. Details from the above address. Library subscription details are also available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by Magnum Distribution Ltd., Cloister Court, 22–26 Farringdon Lane, London EC1R 3AU. Tel: 01–253 3135.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published monthly by the **British Interplanetary Society Ltd.,** 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L., Ltd., Aylesbury, Buckinghamshire, England.

* * *

SOVIETS in SPACE

Mir's Double Anniversary

February 1989

- **The launch of the Mir Space Station into orbit on February 20, 1986.**
- **The start of continuous manned operations on February 5, 1987.**

To commemorate Mir's Double Anniversary, the February 1989 issue of *Spaceflight* includes special features on the Soviet Space Programme under the theme title of 'Soviets in Space'.

***Spaceflight* has long been recognised as a leading Space Publication within the Soviet Union, where a Soviet edition of the magazine has been distributed for many years.**

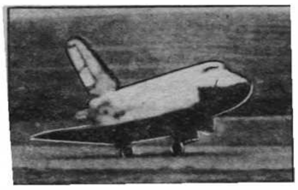
Front Cover: (Main Picture) The Soviet Union's Mir space station, seen from an approaching Soyuz capsule.
(Top Insert) Cosmonaut Yuri Romanenko prepares his space suit before making an EVA in 1977. A major feature on space walks from the Salyut space stations begins on p.45.
(Lower Insert) Cosmonauts Yuri Romanenko and Alexander Laveikin wave to the cameras before boarding Soyuz TM-2 to begin the continuous manning of the Mir space station.

The Coming of Glasnost

The political change which has swept through the Soviet Union is beginning to show its presence in that nation's space programme. *Spaceflight* has long been recognised as a source of information on Soviet space activities. It welcomes the arrival of Glasnost and the opportunity of providing readers with even greater detailed coverage.

Recent events have illustrated the new openness:

- The crew and launch time of Soyuz T-15 in March 1986 was announced in advance. This practice has been continued for all Soviet manned missions.
- The Soviet Union has offered its space facilities for commercial use.
- Other nations were invited to participate in the Soviet Union's planetary exploration programme. For example the Phobos probe and the Mars 94 project. There have been numerous invitations from Soviet space officials for a joint US/Soviet manned mission to Mars.
- Failures in the Soviet space programme are no longer concealed and are openly discussed in the Soviet press. The failure of a Proton rocket in early 1988 was reported, whereas previously news of Soviet launch failures only came from Western space analysts. The world watched in September 1988 as two cosmonauts seemed marooned in orbit, the traditional news blackouts were replaced by full reports.
- In mid-1988 the Soviet press agency, Tass, began to announce the launch vehicle of Soviet satellites, including military launches.
- Western journalists have been allowed access to the Baikonur Cosmodrome. Tim Furniss, Fellow of the British Interplanetary Society, was at Baikonur for the launch of the joint Soviet/French mission in November 1988 (see 'Correspondence').
- The Soviets' plans for the Mir space station were revealed at a press conference prior to the joint Soviet/French mission. During the first quarter of 1989 a module as large as the original station will be docked to Mir. The module will carry the Soviet Union's Manned Manoeuvering Units (MMU). Cosmonauts Aleksandr Viktorenko and Aleksandr Serebov will test the MMUs when they take over from the present Mir crew in April. Journalists at the Baikonur Cosmodrome were shown one of the new style space suits with its MMU attached, they were permitted to take photographs.

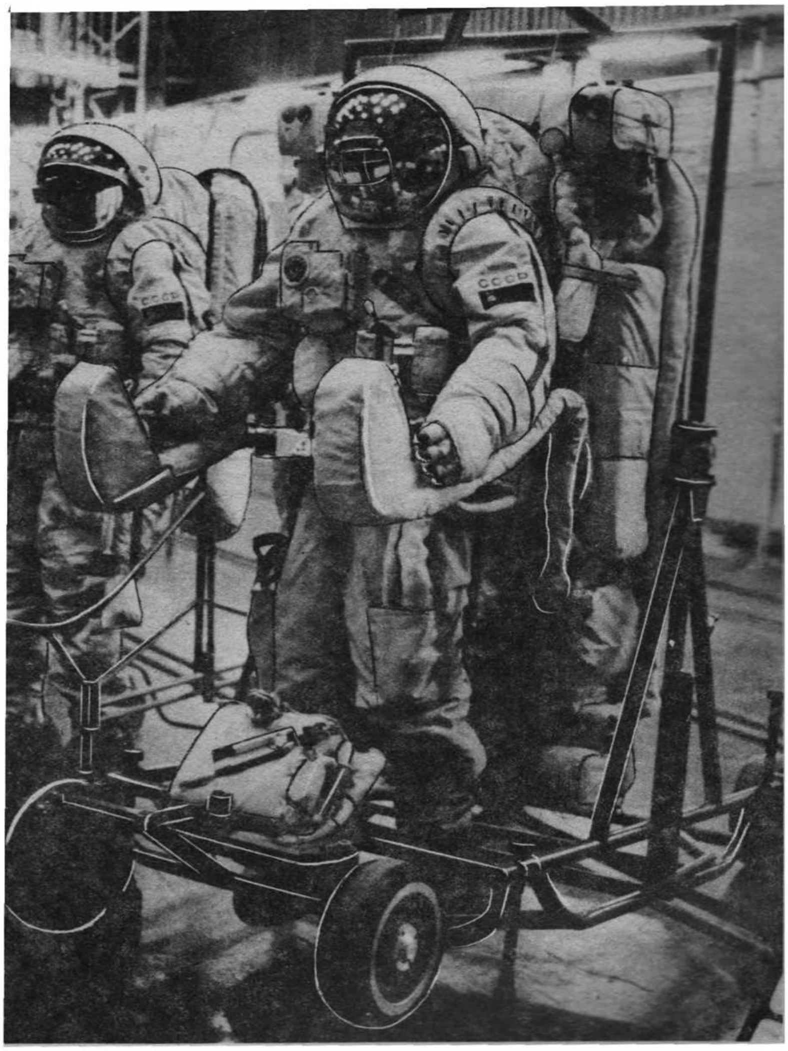


- Most recently we have seen the unveiling of the Soviet space shuttle, Buran. This was the first time a Soviet manned spacecraft was revealed in advance of its first test flight.

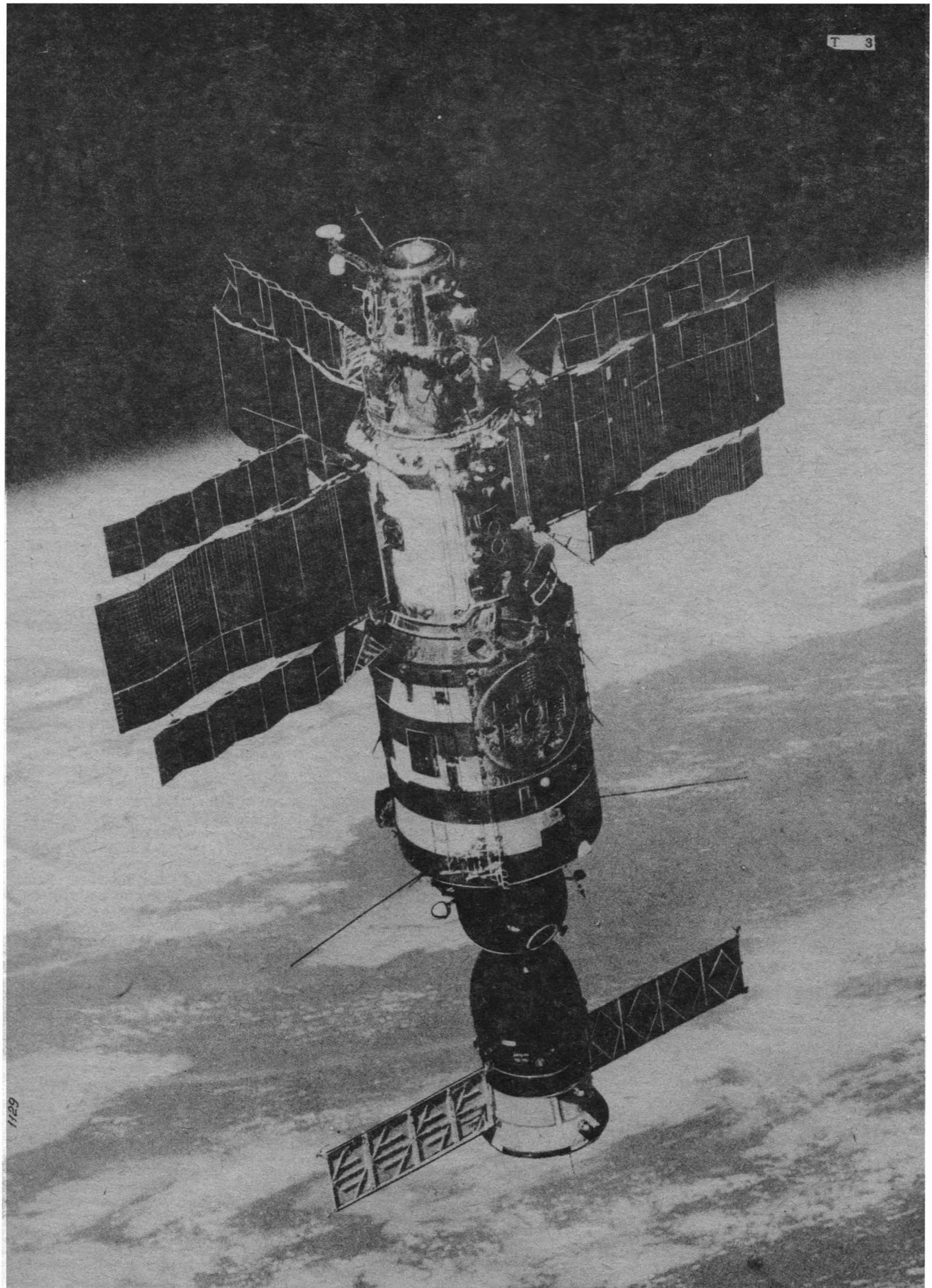
'Soviets in Space' continues on p.45.
***Peter R. Bond* writes about 'Shuttle Glasnost' on p. 50.**

Soviet MMU Revealed

The Soviet Union has displayed its Manned Manoeuvring Unit to the press at the Baikonur Cosmodrome. The back-pack is to be tested later this year outside the Mir space station. *Tim Furniss*



The Salyut 7 space station, with a Soyuz craft docked to its rear port. The station was launched in April 1982, and remains in orbit to this day. Salyut 7 received ten Soyuz spacecraft during its operational period. In 1986 it was boosted into a higher orbit to delay its reentry. Soviet space officials have recently announced that the 19 tonne space station will be returned to Earth by the Buran Space Shuttle.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STS-27 MISSION REPORT

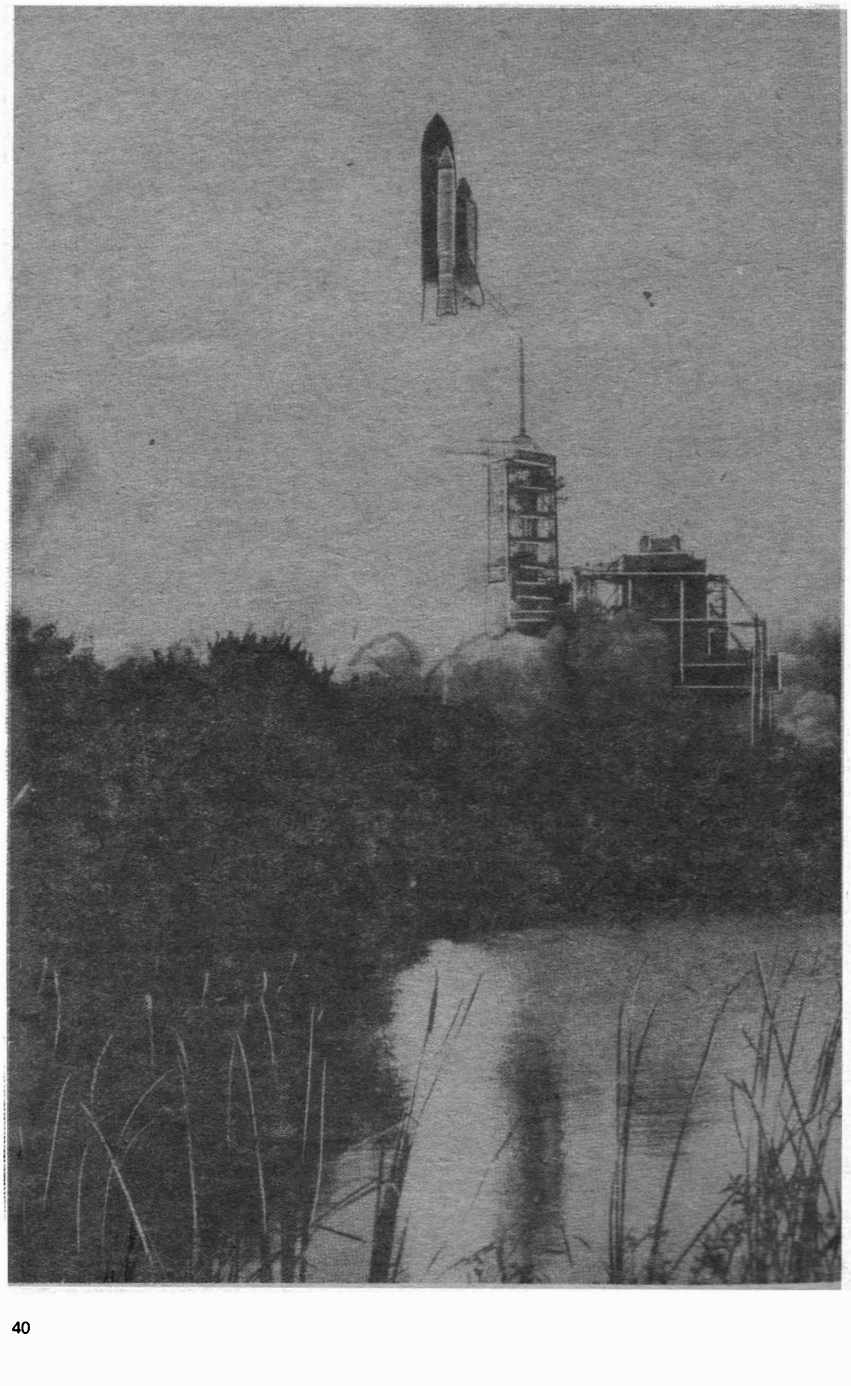
Atlantis in Action

Space Shuttle mission STS-27 was a classified military flight. During the four-day flight, the massive Lacrosse reconnaissance satellite was deployed. *Spaceflight* provides an insight into this secret Department of Defense mission.

By Roelof Schuiling
At the Kennedy Space Center
and
Steven Young

The Space Shuttle Atlantis, carrying a crew of five and a classified military payload, lifted off from the Kennedy Space Center's launch pad 39B on December 2, 1988. The lift-off came at 14:30:34 GMT within minutes of the 11:32 to 14:32 launch window closing.

STS-27 with the space shuttle Atlantis shortly after lift-off from Pad 39B at the Kennedy Space Center. *NASA*



In keeping with the classified nature of the flight, the countdown status was not revealed until the "T minus nine minutes and counting" point.

The landing was at Edwards Air Force Base, California at 23:36:10 GMT on December 6. The crew; Commander Robert 'Hoot' Gibson, Pilot Guy Gardner, together with Mission Specialists Richard 'Mike' Mullane, William Shepherd and Jerry Ross were met by NASA Administrator James Fletcher, who called the mission "a great flight, a super flight."

The mission, designated STS-27, was Atlantis' first flight in three years. The previous launches for Atlantis were STS 51-J on October 3, 1985 and STS 61-B on November 11, 1985.

Launch Preparations

The Atlantis had a smooth launch preparation period. The stacking of the Solid Rocket Boosters (SRBs for STS-27 took just under three months, beginning on July 30 and finishing on September 20. Atlantis was towed from its bay in the Orbiter Processing Facility to the Vehicle Assembly Building (VAB) during the night of October 22 and was mated with the external tank on October 24. The shuttle stack was rolled out to pad 39B on November 2.

During the course of on-the-pad testing of the orbiter's Auxiliary Power System Units it was noted that an isolation valve in unit 2 was sticking and the valve was replaced. When Atlantis was powered up instrumentation indicated the left inboard main landing gear tyre had a slow leak. The landing gear is inaccessible when the orbiter is mated to the External Tank. If the leak had proved serious a roll back to the VAB would have been necessary. The leak rate was monitored and was determined to be approximately 1.7 psi per day. The tyre held 333 psi on November 30 and it was felt that this was sufficient to allow the mission to proceed as the minimum acceptable tyre pressure was approximately 275 psi.

Launch Day

The December 2 launch of STS-27 was delayed until the last minute by upper level winds that exceeded launch limits. Similar weather had prevented the launch of Atlantis the previous day.

The countdown went ahead when the high level winds died down. At T-31 seconds a hold was ordered, cloud cover at the Trans-Atlantic abort

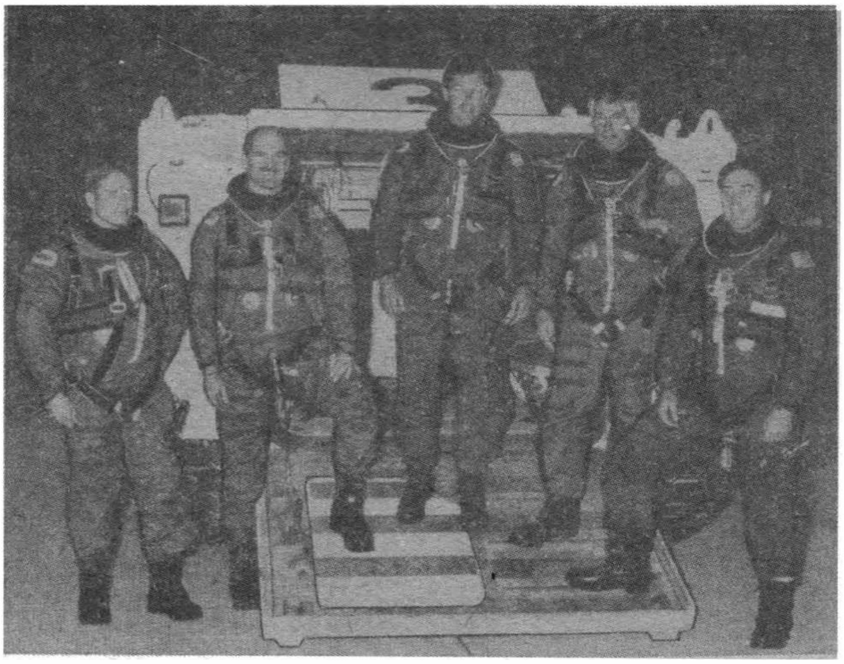
site in Zaragosa Spain had reached over 50%. The countdown was resumed when the Mission Management Team decided the cloud cover was not a problem, if an abort had occurred the skies would have cleared before landing.

As Atlantis began its roll manoeuver observers on the ground could see this was not a usual 28.5 degree inclination launch. The shuttle was heading towards the maximum permitted inclination of 57 degrees. This high inclination orbit would cover most of the Soviet Union. The launch trajectory closely followed the Eastern coast line of the US.

During the ascent the voice transmissions between the shuttle and mission control were not broadcast by NASA. However unscrambled ground to air transmissions could be monitored with a UHF radio.

The SRB separation took place normally and the boosters were returned to Cape Canaveral Air Force Station on December 3. When the booster segments were disassembled engineers found no signs of hot gases reaching the O-rings.

The Atlantis launch was a direct ascent to orbit, requiring just one Orbital Manoeuvering System (OMS) burn to circularise the spacecraft's orbit.



The five crew members of STS-27, dressed in their partially pressurised flight suits, stand in front of an M1-13 armoured personnel carrier at the Kennedy Space Center's Shuttle Landing Facility. The M1-13, for which the crew is being trained, is used during emergency egress situations. From left to right: William Shepherd; Guy Gardner; Robert 'Hoot' Gibson; Richard (Mike) Mullane; and Jerry Ross. *NASA*

Satellite Deployment

After completing post-ascent checks the crew were given a go-ahead to begin on-orbit operations. The $500 million Lacrosse satellite was deployed approximately five hours into the flight during Atlantis' sixth orbit of the Earth.

A final checkout of Lacrosse's onboard systems was made before the crew were given permission to deploy the satellite. Mission Specialist Mike Mullane, using the Remote Manipulator System (RMS), lifted the satellite from its cradle in the payload bay and positioned it in space above the orbiter. Once he was sure the satellite was stable he released the grapple fixture in the 'wrist' of the RMS.

Atlantis' crew then stood by to observe the deployment of Lacrosse's large solar array. It was reported that the first attempt to deploy the panels failed. Astronauts Ross and Shepherd were prepared to make a spacewalk to manually open them. Ross has over 11 hours EVA experience; he made two space walks to erect the EASE and ACCESS structures in the payload bay during a previous shuttle mission (STS 61-B). The emergency EVA was not necessary, ground control sent a second command to deploy the solar panels and the array opened.

The Lacrosse satellite is able to operate night and day regardless of weather conditions. The Pentagon hopes the satellite will be able to locate Soviet mobile missile systems, even when they are concealed amongst trees.

Serious Tile Damage

The crew observed substantial tile damage to the orbiter's right hand side using the camera at the end of the RMS. Television pictures of the launch showed a shower of debris during the SRB separation. The debris is believed to have caused the tile damage.

One possible source of origin for the debris was the External Tank, which, constructed five years ago, was the oldest External Tank to fly. The tank was also used for tests at Vandenberg Air Force Base, during which it was filled with cryogenic propellants. It is possible the External Tank's thermal insulation was affected during these tests by the super-cold fuel, weakening it enough to break away from the tank when the SRB separation motors fired.

About 700 tiles were damaged and about 150 will have to be replaced before Atlantis' next flight.

There was one other significant malfunction during the flight: water from a evaporation collector pooled in the crew compartment. The water was removed by the crew and a back-up system was brought into use.

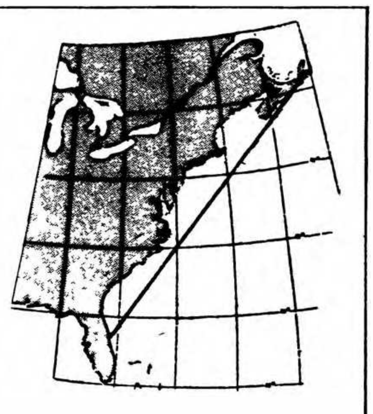
Atlantis was returned to the Kennedy Space Center by the 747 Shuttle Carrier Aircraft on December 13.

STS-27 at a Glance

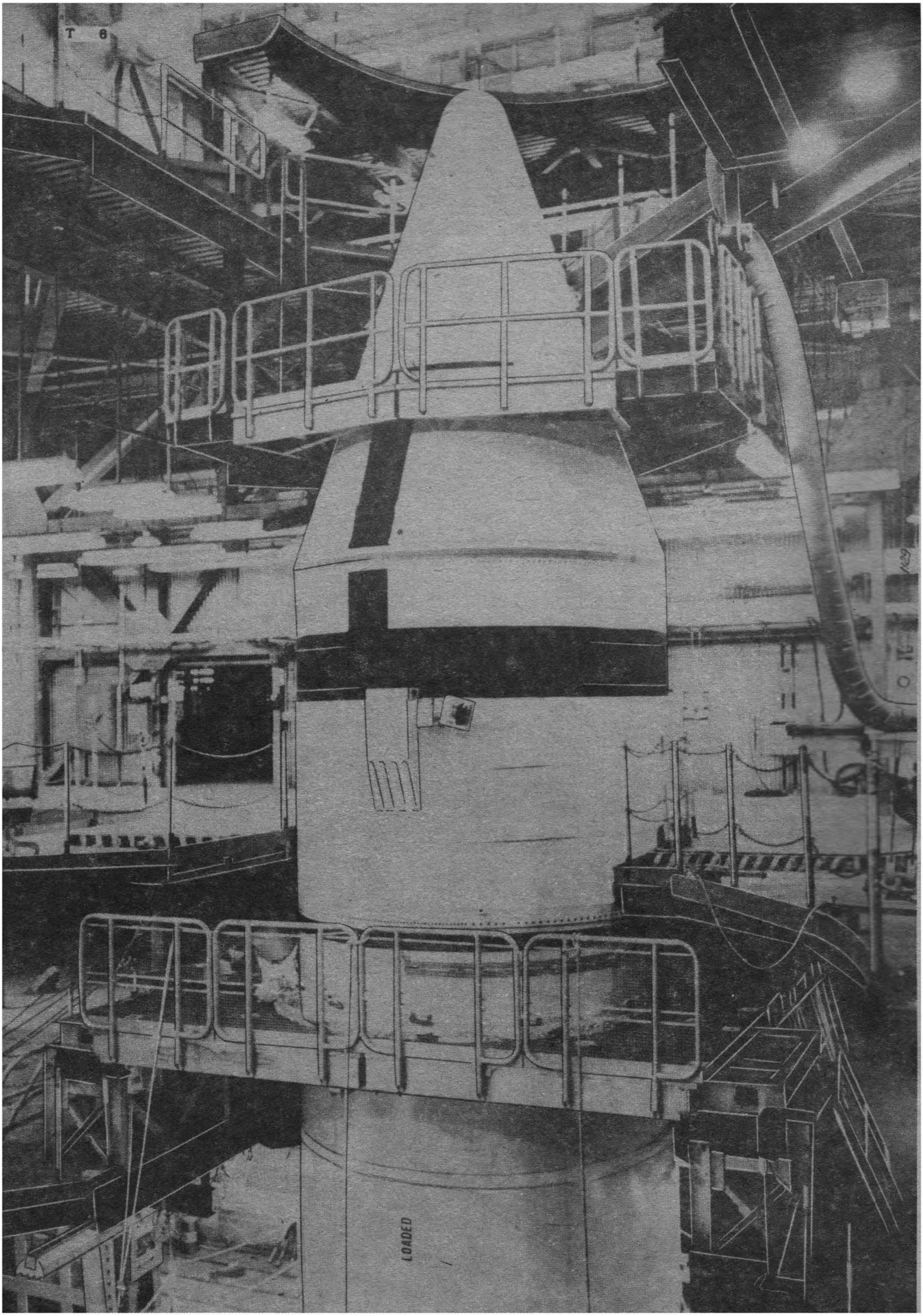
LAUNCHED: 14:30:34 GMT, December 2
LAUNCH SITE: Pad 39B, Kennedy Space Center, USA
LANDED: 23:36:10 GMT, December 6
LANDING SITE: Runway 17, Edwards Air Force Base, USA
ORBIT: approx. 390-460km
INCLINATION: 57 degrees
DURATION: 105hrs 5min 24sec

COMMANDER: Robert 'Hoot' Gibson
PILOT: Guy Gardner
MISSION SPECIALISTS:
Richard 'Mike' Mullane
William Shepherd
Jerry Ross

PAYLOAD: Lacrosse



The launch trajectory for STS-27. The 57 degree inclination of the orbit resulted in a flight path that followed the East coast of the US.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INTERNATIONAL SPACE REPORT

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Deal on ESA Funding

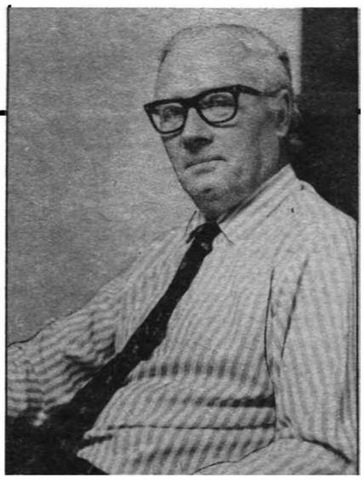
In return for the UK's approval for a 5% increase in funding for the European Space Programme, the ESA Council has agreed to conduct an independent review of the costs and management of the ESA Science Programme. The move is seen as a 'U' turn in UK space policy. The Government had previously said it was unconvinced that the increase was justified.

The agreement was reached at a meeting of the ESA Council on December 15, 1988. The ESA Science Programme, known as Horizon 2000, includes the Soho/Cluster mission (***Spaceflight***, October 1988, p.382) and the Cassini probe to Saturn and its moon Titan (***Spaceflight***, January 1989, p.9). The decision to increase the funding had to be unanimous. The UK's initial disapproval threatened to prevent the other ESA nations from going ahead. It was suggested that Britain could lose its ESA membership if it blocked the extra funding.

The UK's agreement to support the budget increase does not indicate a change in the Government's general space policy. If the UK had refused to agree it would have found itself isolated, all the other ESA nations were in full support of the increase. The Government had little choice, agree or face possible expulsion from ESA. Britain has been seen as the 'financial conscience' of ESA and demanded an independent review into the organisation and management of the ESA science programme, with the objective of making the programme more cost effective.

The British delegation was led by Mr Arthur Pryor, the Director General of the British National Space Centre. He said. "The United Kingdom fullysupports this agreement which demonstrates our continued commitment to Horizon 2000 as the centrepiece of our space science research. We also welcome the ESA Council's collective resolve to maintain cost discipline on Horizon 2000 and to seek the most cost effective use of the extensive resources committed to this programme."

Director of ESA's scientific programme, Professor Roger Bonnet commented on the agreement."The Council's unanimous decision was one of extreme importance to the scientific programme. It shows a great will to go forward together."



Arthur Pryor *BNSC*

The next shuttle launch, STS-29, was scheduled for launch on February 23, 1989, at the time of going to press. Its left-hand Solid Rocket Booster (SRB) is shown here in the Vehicle Assembly Building shortly after the nose cap had been placed on top of the SRB stack. *NASA*

SATELLITE DIGEST – 218

Robert D. Christy

Continued from the December 1988 issue

A monthly listing of satellite and spacecraft launches, complied from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

GORIZONT 16, 1988–71A, 19397
Launched: 1952, 18 August 1988 from Tyuratam by D–1–e.
Spacecraft data: Stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing continuous telephone, telegraphic and television links both within the USSR and abroad.
Orbit: Geosynchronous above 80 degrees east.

COSMOS 1964, 1988–72A, 19412
Launched: 1050, 23 August 1988 from Tyuratam by A–2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 15 days.
Orbit: 231 × 285 km, 89.70 min, 70.00 deg.

COSMOS 1965, 1988–73A, 19414
Launched: 1115, 23 August 1988 from Plesestk by A–2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, recovered after 30 days. All or part of the payload was an Earth resources package operating under the 'Priroda' programme.
Orbit: 257 × 277 km, 89.92 min, 82.36 deg, later manoeuvred to 339 × 355 km, 91.54 min, 82.33 deg.

OSCAR 25 & OSCAR 31, 1988–74A&B, 19419 & 19420
Launched: 0712, 25 August 1988 from Vandenberg AFB by Scout.
Spacecraft data: Transit-type navigation satellites.
Mission: Pair of navigation satellites.
Orbit: 1036 × 1182 km, 107.53 min, 89.99 deg.

INTERNATIONAL SPACE REPORT

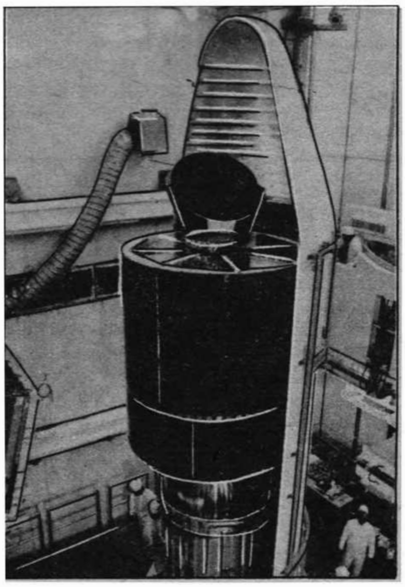
SOYUZ-TM 6, 1988–75A, 19443
Launched: 0423*, 29 August 1988 from Tyuratam by A–2.
Spacecraft data: Near-spherical orbital compartment carrying a rendezvous radar tower, conical re-entry module and cylindrical instrument unit with a pair of solar panels, and containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried Soviet/Afghan crew of Vladimir Lyakhov, Valery Poliakov and Abdul Ahad Mohmand to Mir. Docking with Mir's rear port occurred at 0541 on August 31. Lyakhov and Mohmand returned to Earth in Soyuz-TM 5, landing at 0050 on September 7, following abortive landing attempts on September 6. At 0105 on September 8, with Titov, Manarov and Poliakov aboard, it undocked and then re-docked at Mir's forward port, 20 minutes later.
Orbit: Initially 195 × 228 km, 88.66 min, 51.57 deg, then by way of a 234 × 259 km transfer orbit to a rendezvous with Mir in an orbit of 339 × 366 km, 91.53 min, 51.62 deg.

USA 31, 1988–77A, 19458
Launched: 1205*, 2 September 1988 from Cape Canaveral by Titan 34D/IUS.
Spacecraft data: not available.
Mission: Electronic-intelligence gathering from geosynchronous orbit. The IUS reportedly failed to operate correctly.
Orbit: near-geosynchronous.

USA 32, 1988–78
Launched: 5 September 1988 from Vandenberg AFB by Titan 2.
Spacecraft data: Parent satellite and a cluster of (probably) three sub-satellites, joined together by several-kilometre long wires to maintain formation.
Mission: Electronic-surveillance over Ocean areas.
Orbit: 1050 × 1170km, 107.5min, 63.4 deg (approximate orbit).

COSMOS 1967, 1988–79A, 19462
Lauched: 1030, 6 September 1988 from Plesetsk, USSR by A–2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 9 days.
Orbit: 228 × 278 km, 89.61 min, 72.88 deg.

FENGYUN 1, 1988–80A, 19467
Launched: 2030, 7 September 1988 from Taiyuan by Long March 4.
Spacecraft data: Rectangular, box-shaped body, about 1.5 m long on each side, and equipped with a pair of solar panels parallel with one face. The mass is 750 kg.
Mission: Meteorological satellite in sun-synchronous orbit, returning cloud-cover pictures and other weather data.
Orbit: 881 × 904 km, 102.90 min, 99.12 deg.



Payload installation prior to the launch of Japan's Sakura 3B communications satellite on September 16, 1988 (see below).
NASDA

GSTAR 3, 1988–81A, 19483
Launched: 2300*, 8 September 1988 from Kourou by Ariane 3.
Spacecraft data: Three-axis stabilised, box-shaped body, 1.63 × 1.32 × 0.99 m, with an aerial array at one end. Power is provided by a 14.3 m span solar array. The mass is 759 kg (in geosynchronous orbit).
Mission: US domestic comsat, including the Geostar radio-location package. Improperly-loaded fuel meant the satellite was unbalanced and it tumbled during the apogee-motor firing, producing an incorrect, unusable orbit.
Orbit: 16587 × 36160 km, 982.98 min, 1.52 deg.

SBS 5, 1988–81B, 19484
Launched: 2300*, 8 September 1988 from Kourou, Guyana by Ariane 3.
Spacecraft data: Cylindrical, spin-stabilised body with a de-spun aerial array. The length is 6.6 m (excluding aerials), and the diameter 2.2 m. The mass is 725 kg (in geosynchronous orbit).
Mission: US domestic comsat, providing point-to-point services for business users in the continental United States.
Orbit: geosynchronous above 122 deg west.

COSMOS 1968, 1988–82A, 19488
Launched: 1040, 9 September 1988 from Plesetsk, USSR by A–2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, recovered after 14 days. All or part of the payload was an Earth resources package operating under the 'Priroda' programme
Orbit: 260 × 275 km, 89.93 min, 82.34 deg.

PROGRESS 38, 1988–83A, 19486
Lauched: 2334*, 9 September 1988 from Tyuratam by A–2
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carrying a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried equipment and consumable supplies to the resident crew of Mir. It docked with Kvant's aft-facing hatch at 0122 on July 20. It undocked on October 23 and was de-orbited the same day.
Orbit: Initially 186 × 246 km, 88.77 min, 51.63 deg, then by way of a 234 × 332 km transfer orbit to a docking with Mir in an orbit of 337 × 363 km 91.47 min, 90.62 deg.

COSMOS 1969, 1988–84A, 19495
Launched: 1500, 15 September 1988 from Plesetsk by A–2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 168 × 348 km, 89.68 min, 67.14 deg, manoeuvrable.

COSMOS 1970–1972, 1988–85A–C, 19501–19503
Launched: 0201, 16 September 1988 from Tyuratam by D–1–e.
Spacecraft data: not available
Mission: Single launch of a triplet of GLONASS (Global Navigation Satellite System) vehicles.
Orbit: 19115 × 19146 km, 675.75 min, 64.87 deg.

SAKURA 3B (CS–3B). 1988–86A, 19508
Launched: 1000, 16 September 1988 from Tanegashima by H–1
Spacecraft data: Cylindrical body, 2.8 m long and 2.2 m diameter. The mass is 1099 kg (in geosynchronous orbit).
Mission: Japanese built and launched communications satellite.
Orbit: geosynchronous above 136 deg east longitude.

OFFEQ 1, 1988–87A, 19519
Launched: 0932*, 19 September 1988 from Palmachim by Shavik.
Spacecraft data: Octagonal frustrum, 2.3 m long and varying from 0.7 m to 1.2 m diameter. The mass is 156 kg.
Mission: Israeli built and launched space-technology experiments satellite.
Orbit: 247 × 1155 km, 98.65 min, 142.87 deg.

Above the Planet

Salyut EVA Operations

With the advent of the Mir Complex, and its permanent manning, the Soviet Union has demonstrated a confidence and willingness to undertake work outside the orbital complex on a regular basis for both planned and unplanned tasks.

The EVAs from the Mir complex have been described in the relevant parts of the Mission Report series.

However, one factor in the Soviet confidence in the use of men outside the complex for tricky, and sometimes dangerous, repair and retrieval tasks, was the experience gained during the EVAs conducted during the Salyut 6 and Salyut 7 missions.

Before Salyut

The Soviet Union's cosmonauts undertook two EVAs in the 1960s. The first was that of Aleksei Leonov. On March 18, 1965 the cosmonaut made the first excursion by man outside his spacecraft whilst in orbit. He spent 12 minutes and 9 seconds outside the craft Voskhod-2. The cosmonaut had spent 24 minutes exposed to the vacuum of space inside and outside of the flexible airlock attatched to the side of the Vostok-derived spacecraft. Despite Soviet claims of a perfect EVA, it emerged later that Leonov had expended a great deal of energy during the short excursion and had to reduce the pressure in his suit to clamber back into the airlock. His companion on the flight was the late Pavel Belyayev.

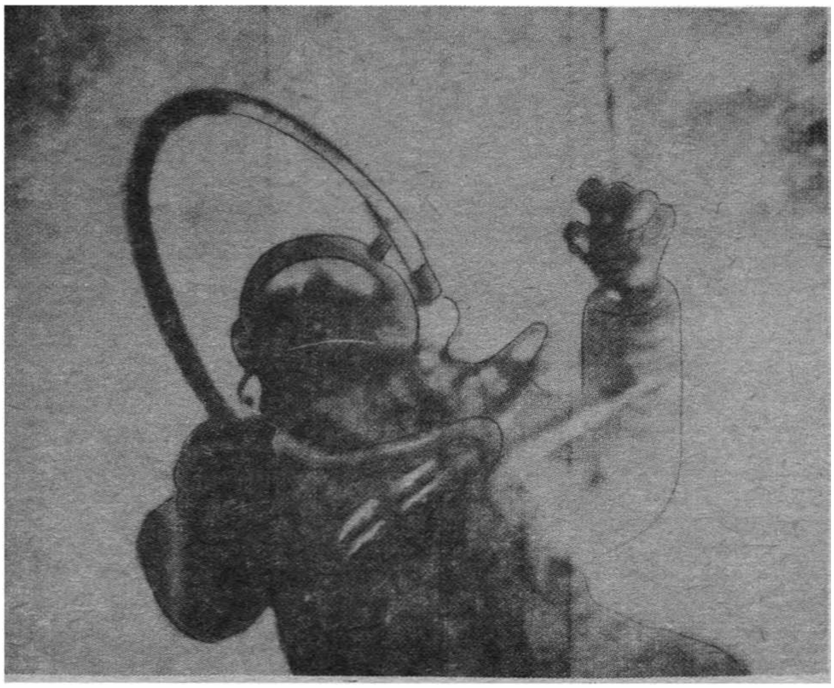
The Soviets have recently revealed that a further Voskhod EVA mission was planned. In this one, which would presumably have repeated Leonov's task, a woman cosmonaut would have been the spacewalker. Valentina Tereshkova was pictured in an EVA suit. Had she conducted the mission she would have become the first woman to fly into space twice and the first to undertake a spacewalk. Those records, however, would have to wait for another 21 years.

The Soviets concelled further Voskhod missions after Leonov's.

In the period 1965–1969 there was much discussion about a Soviet Lunar mission, aimed at beating the Americans to the Moon.

One of the preparatory features of the programme probably involved the docking together in near-Earth orbit of two Soyuz spacecraft, the successor to Vostok / Voskhod. This would accomplish the manoeuvres achieved by the American moonship precursors – the Gemini spacecraft. Two cosmonauts would then transfer outside the spacecraft from one to the other demonstrating the Soviet prototype EVA suit.

The mission was to be flown in April 1967 and was reportedly ordered by the Soviet government even though



Soviet cosmonaut Aleksei Leonov becomes the first man to step outside his spacecraft during the Voskhod-2 mission in 1965. *All Photographs Novosti*

By Neville Kidger

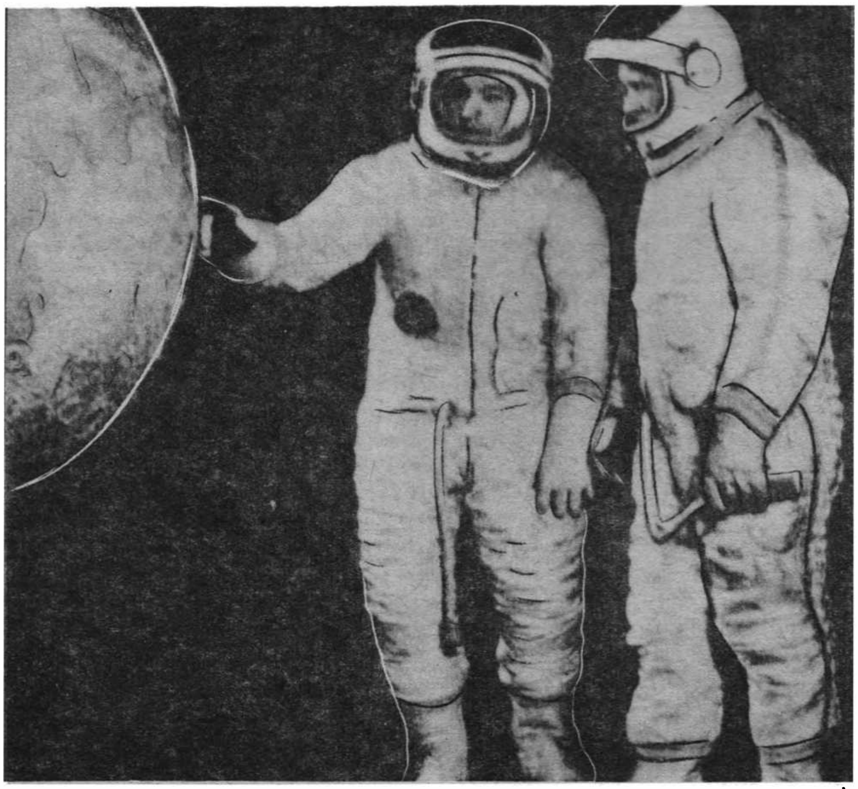
Soviet engineers and designers thought the plan to be risky and premature for the first piloted flight of the new spacecraft, even though it had flown unmanned.

Nonetheless, on April 24, 1967, Soyuz 1 was launched with cosmonaut Vladimir Komarov. The plan to launch Soyuz 2 the next day for a docking with Soyuz 1 and the transfer of two men *via* open space was scrapped when as-yet-unknown problems caused the recall of Soyuz 1 after just one day in space. Tragically, Komarov was killed with his descent cabin impacted the Earth. The Soviets say that his parachute lines tangled.

The Soyuz 2 crew of Valeri Bykovski, Aleksei Yeliseyev and Yevgheni Khrunov, was stood down pending the investigation.

Twelve years afterwards the Soviet released a photograph which showed the two spacewalker cosmonauts – Yeliseyev and Khrunov – looking at a globe of the Moon. This picture was probably taken to illustrate the ancestry of the Lunar space suit, when it was eventually used. There appears to be no other illustration of cosmonauts in similar situations.

In January 1969 Yeliseyev and Khrunov did perform their EVA. They took an hour to cross from Soyuz 5 to Soyuz 4 in which they returned to Earth. However, the flight had no purpose beyond propaganda for the Lunar programme – the Americans were about to win that race – and little value for the space station programme the Soviets were about to embark upon – automatic Soyuz dockings had been performed before.



Cosmonauts Yeliseyeve and Khrunov looking at a globe of the moon. The picture shows the Soyuz-1 EVA suit which might have been taken as a basis for a lunar space suit.

Salyut 1

Due to the limited use of the first Salyut station (one mission terminated with the crew unable to enter the station and the second curtailed early with the resulting deaths of the three men aboard Soyuz 11) it is not known if EVAs from the station were contemplated. However, photographs of the station on Earth do not appear to show an EVA hatch.

A picture has been published in the west showing a cosmonaut on a tethered EVA exiting from the docking port at the front of the station. However, no Soyuz is shown. Because the origins of the picture are unknown to this writer it is difficult to evaluate its potential as a serious EVA scenario. Question: where would the manned Soyuz have been?

In 1972 the Soviets reportedly tried to buy a number of American pressure suits. The purchase was stopped by the American government.

1973 Revelations

In April 1973 the Soviets launched Salyut 2. Within two weeks of its launch it had broken up in Earth orbit. Transmissions identified it as a military version of the Salyut station.

On May 11, 1973 a new Salyut was launched, this time a civil version. The station experienced a problem on its very first orbit which caused it to waste all of its attitude control fuel. The Soviets abandoned it in orbit and called it Kosmos 557, passing it off as a routine science satellite.

Both Kosmos 557 and Salyut 2 decayed from orbit within six days of each other in late-May 1973.

It was later revealed that Aleksei Leonov had been training for the civil Salyut. With his background it is possible that EVAs were contemplated from Salyut / Kosmos 557. However, with the loss of the station, Leonov and his other crewmates were transferred to the joint USSR/USA ASTP mission.

In June 1973 a delegation from the western press was allowed into Star Town, near Moscow to view the Soviet's expanding facilities for cosmonaut training. Whilst there, Vladimir Shatalov showed the delegation a mock-up of a Salyut station with three solar panels located further aft than the first pair of solar wings of Salyut 1.

Also in evidence, on the transfer compartment, was a circular hatch. Contemporary accounts wondered if this was an EVA hatch. Later revelations showed these speculations to be correct.

Military Salyuts

Salyut 2 transmitted on a separate frequency to the civil Salyuts and that station's successor, Salyut 3, exhibited the same characteristics.

Because the actual configuration of the military Salyuts 2, 3 and 5 has yet to be disclosed by Soviet authorities, we cannot know what, it any, EVA capabilities these stations possessed.

The stations were designed by the Chelomi Bureau, as are the heavy Kosmos modules which have been docked with Salyuts 6 and 7. These modules do not appear to possess an EVA hatch. It seems unlikely, therefore, that there was a possibility, or requirement, for an EVA from the military stations.

In October 1976 the Soyuz 23 mission to the Salyut 5 station was aborted when problems surfaced during rendezvous between the ship and station. The flight engineer of that mission, Valeri Rozhdestvenski, was described as a member of a special training programme involving zero-g simulations and parachute drops. He had also completed a four-year stint as the commander of a deep-sea diving group in the Baltic. Some western interpretations of this led to the belief that EVA was a part of the mission. However, there is no further evidence of any EVA involvement for the cosmonaut.

Salyut 4

The Salyut model shown in 1973 was eventually revealed as Salyut 4, which was placed into orbit on December 26, 1974.

The first expedition to the station lasted 30 days and was the first successful mission to a civil Salyut station. The Gubarev / Grechko crew apparently had no EVA plans.

The second crew, Lazarev and Makarov, may have been different. They were launched on April 5 1975 with the intention of spending two months in space. However, their Soyuz rocket ran into problems during the separation of its second and third stages with the result that the men conducted a sub-orbital flight which saw them escape narrowly from death.

The back-ups for the flight, Klimuk and Sevastyanov, were launched on May 24, 1975 and spent 63 days in space with no EVAs.

In May 1976, Klimuk revealed that EVA work was a part of the two men's mission but had been dropped because of scheduling and training problems. He did reveal that EVAs were to be part of future missions.

The next station to be launched, however, was the military Salyut 5.

Salyut 6

Salyut 6 was lofted into orbit on September 29, 1977 and the first crew to be launched to it, cosmonauts Vladimir Kovalenok and Valeri Ryumin,

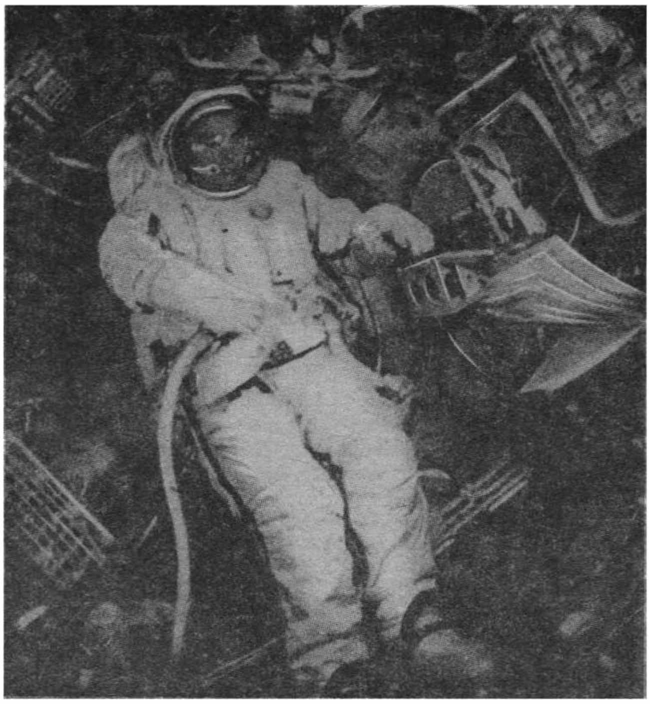
(Top left) Georgi Grechko in the Salyut 6 airlock.

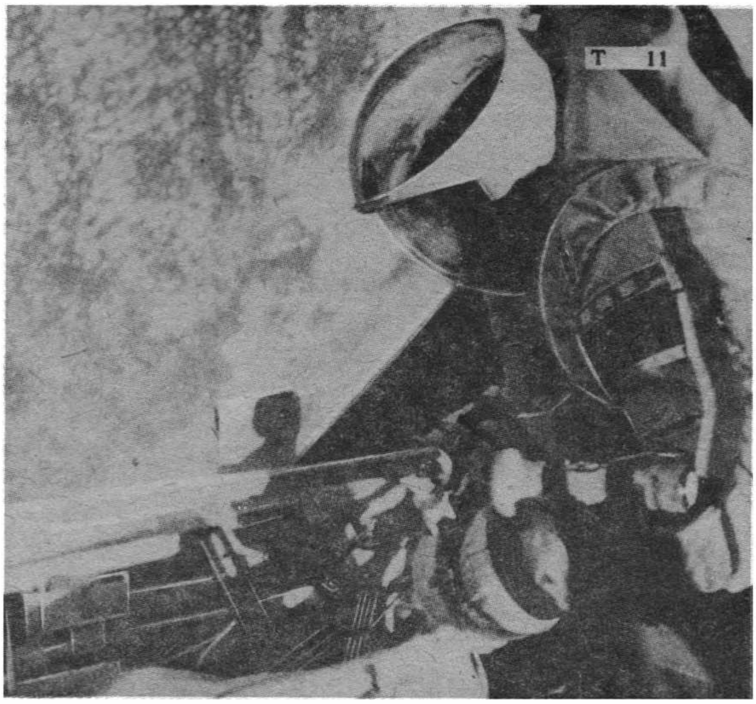
(Top right) Leonid Kizim repairing the Salyut 7 propulsion system.

(Centre) EVA specialists: (left to right) Vladimir Solovyov, Vladimir Dzhanibekov, Svetlana Savitskaya and Leonid Kizim.

(Bottom left) Training for EVAs in the water tank at Star City.

(Bottom right) Romanenko wearing his EVA suit onboard Salyut 6.

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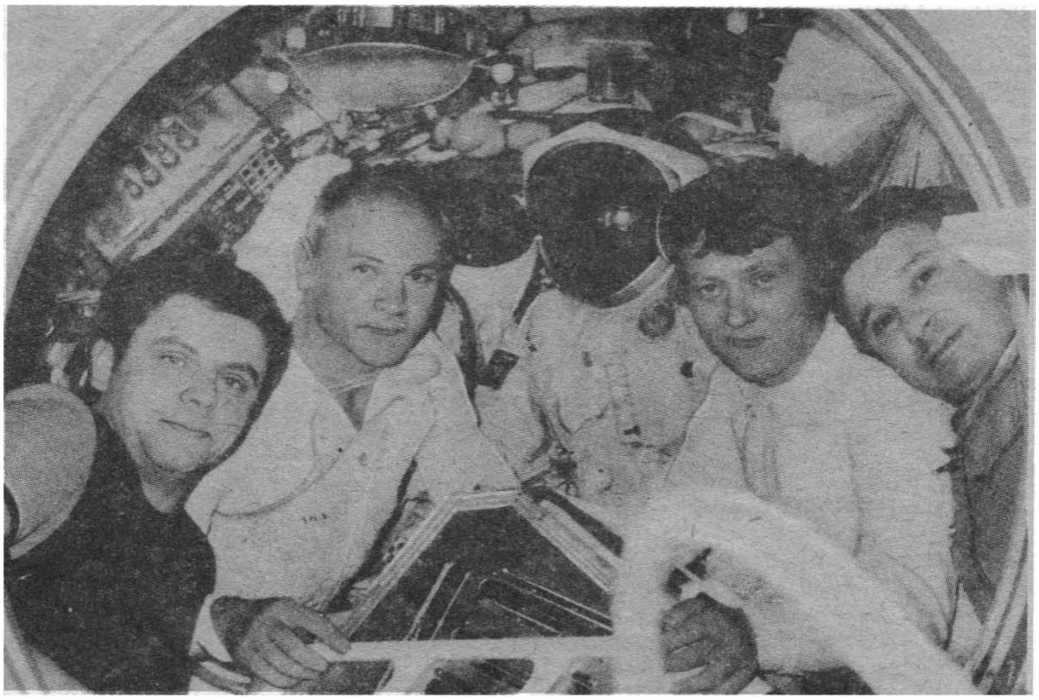
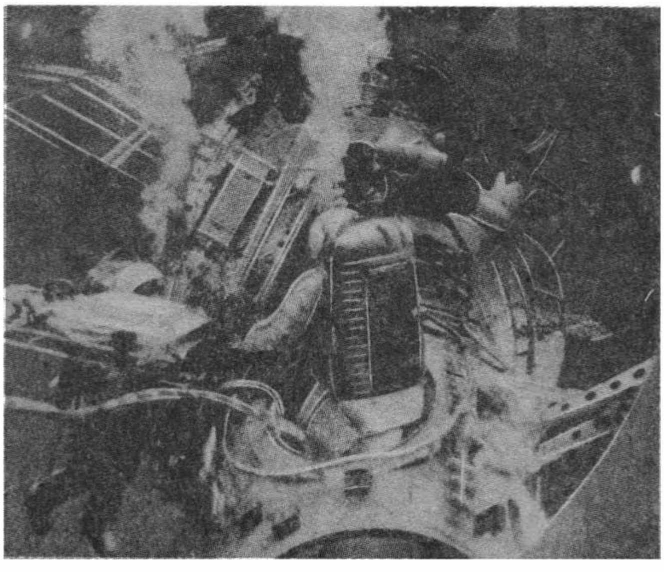
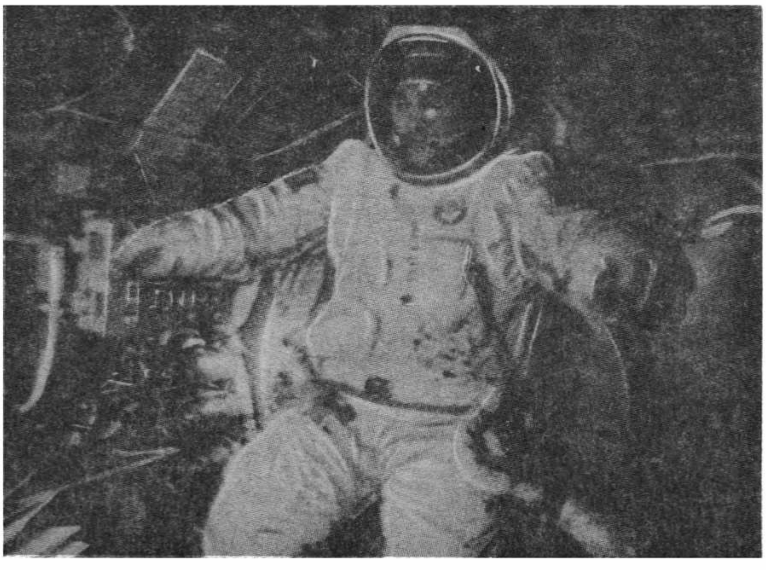
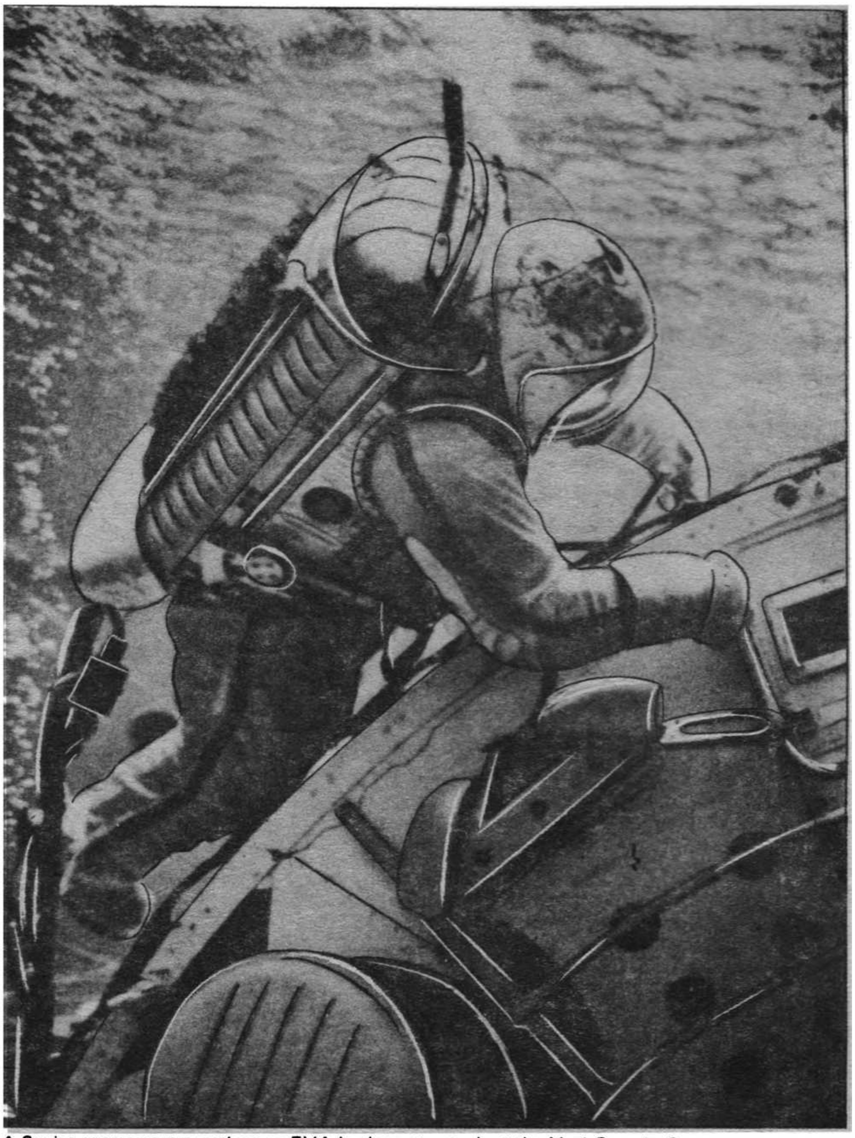








A Soviet cosmonaut practices an EVA in the water tank at the Yuri Gagarin Cosmonauts Training Centre.

followed on October 9, on Soyuz 25.

Because the spacecraft was launched with a blaze of publicity there was speculation in the west that the upcoming 60th anniversary of the October Revolution in the USSR would see a spacewalk as a spectacular celebration of the event.

But the Soyuz 25 crew returned home after just two days, the victims of a random piece of technical failure. When they had tried to dock with the station's front port the probe of the Soyuz did not capture the drogue of the station.

As many as four attempts were made to achieve a hard dock, and the Soyuz and Salyut were at one time tracked as a single object by western sensors.

The failure led to a reappraisal by Soviet managers. Crews were broken up and reformed to ensure a mixture of experienced and new cosmonauts instead of rookie crews. Then there was the problem of the Salyut docking port.

At the time, it was not known if the problem lay with the Salyut recepticle or the Soyuz docking probe. The probe had been lost when the Soyuz's living quarters were cast off, as planned, after retrofire. It had been destroyed in the atmosphere. The only part of the docking devices left to examine was, therefore, the Salyut front docking cone.

A plan was devised which would see the next cosmonauts to the station go outside the Salyut to examine the cone and the surrounding connections on the docking ring.

Cosmonauts Yuri Romanenko and Georgi Grechko were assigned to the mission. Grechko trained in the water tank at Star Town leaning out of the docking hatch and examining the ring and cone.

On December 10, 1977, Soyuz 26 was placed into orbit manned by Romanenko and Grechko. The next day it docked with Salyut's rear port and the men entered the station. When the Soviets announced the docking it was the first the world knew of Salyut's two docking units.

Grechko later wrote that the docking unit hatch was not intended for EVA work. "The difficulty was to decide which would be better: to proceed with our exit into open space or to return to the station. The station was developing a mounting number of minor faults that were posing a threat to the space walk and, thus, to the station itself," he wrote.

Nine days after launch the preparations for the EVA were complete. After donning their new semi-rigid EVA spacesuits, the cosmonauts depressurised the transfer compartment of Salyut. At 2136 GMT, whilst flying over the southern Pacific Ocean, in bright sunlight, the hatch of the docking unit was opened. Grechko stuck his upper half out of the hatch opening and, using tools passed to him by Romanenko, began the mechanical check of the docking ring. The EVA was timed so that the sunlight illuminated the work. Lights were available for shaded areas.

The experienced flight engineer examined the condition of the individual components of the docking system including the joints, sensors, guide pins, fasteners, sealing surfaces, etc. Grechko was outside for 20 minutes.

He later reported that he had "attentively studied the butt end and the adjoining cowling. The butt end is brand new as though just taken off a machine tool. There are no scratches, traces or dents on it. All of the docking equipment – lamps, electrical sockets, latches – all is in fine order. The receiving cone is also clean, without a single scratch."

With those words Grechko assured the continued full scale operation of the Salyut 6 station.

Salyut passed into darkness about 12 minutes after Grechko had finished his inspection, according to Robert Christy. Contact with the Flight Control Centre (FCC) would soon be resumed. However, presumably around this time, Romaneko decided to have a look outside himself. But he had forgotten that he was not connected to the interior with a safety line and began drifting out. Grechko reached out and pulled him back in.

The story of this incident first emerged at the post-flight press conference and was first widely publicised by James Oberg. However, Oberg has recently noted that the details of the incident have been described by Grechko "in many, many variations, in no small part due to Grechko's own creativity and imagination." The cosmonaut has related how he had to stretch "a long way" to grab Romanenko and "almost didn't get him" to experienced space journalist Henry Cooper. He left that writer with the impression that without interven-

SOVIETS in SPACE

tion Romenko would have floated out of Salyut into an independent orbit and presumably death. Grechko said that he told Romanenko "it's a good thing I caught you."

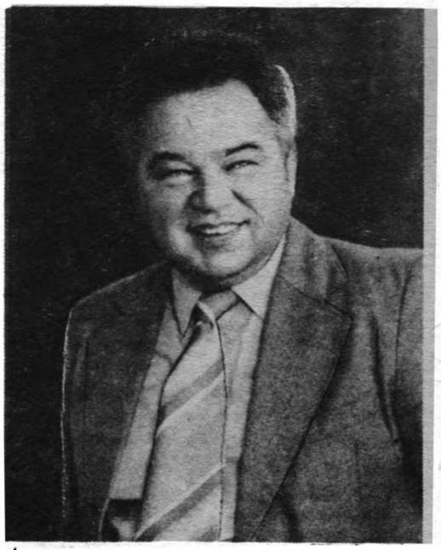
When contact was resumed with FCC there was no mention of the incident. Grechko told the controllers of his findings about the docking unit.

The cosmonauts closed the hatch after it had been opened for 1 hour 28 minutes. However, at this point a problem arose. Telemetry returned to FCC revealed that a valve which bled air out of the transfer compartment to depressurise it had stuck open. If the indication was correct the repressurisation of the compartment would not be possible. The air would simply flow out of the station through the stuck valve.

Deputy flight controller Viktor Blagov later admitted that the FCC staff were "quite worried" at this point.

Instructions were issued to Romanenko and Grechko to begin slowly filling the compartment with air, to determine if it was flowing out into space or repressurising the compartment. As indications of increased pressure in the compartment were received at FCC there was relief.

The fault was eventually traced to a cable fault, possibly caused by condensation. (This also worried the FCC and a search was later made for water. To the relief of all, none was found in the electrics).



Georgi Grechko

Yuri Romanenko

A Stroll Outside : July 29 1978

Vladimir Kovalenok and Aleksandr Ivanchenkov were on the 45th day of their 140-day mission when they conducted the first EVA through the Salyut 6 side hatch. The men's tasks were the removal of samples from Salyut's exterior and attaching replacement samples.

Earlier, officials had said that EVAs would be performed only during malfunctions. Various "hypothetical emergencies" had been formulated on the ground including failure to close the cover for the BST-1M submillimetre telescope, repairs to the solar batteries or other problems which could not be foreseen.

Kovalenok and Ivanchenkov had trained in Star Town's hydro tank for the EVA and had studied videotapes of their training on the station. Two days before they were scheduled to emerge they conducted a full dress rehearsal for the EVA right up to the operations before hatch opening.

On July 29 the men donned their suits and began depressurising the forward transfer compartment of Salyut 6 having sealed themselves into it. Most of the final checks before exiting the station came during a 30 minute pass over the ground stations in the USSR.

At 0357 GMT, a minute earlier than planned, the men were given permission to open the hatch. As the men opened it the complex – consisting of Soyuz 29/Salyut 6/Progress 2 – was over the Sea of Japan.

The "reaping of the scientific harvest" began immediately, whilst the complex was still in daylight. Fixed to the outer skin of the station were three panels containing samples of rubber, plastics, duraluminium, steel, glass and ceramic materials. Ivanchenkov reported that the rubber was in good condition.

These panels had been fixed to the exterior of Salyut before its launch some ten months earlier. A micrometeorite panel was also removed. Later examination showed hundreds of small craters in a 1/16th m^2 area. Konstantin Feoktistov later said that it was practically "raining" meteorites.

A cassette with bio-polymers, the Medusa experiment, was removed. The experiment consisted of three parts – two exterior parts of the cassette with an open and a closed part and a control cassette inside Salyut. The cassettes contained components of nucleic acids. Later examination of these gave researchers a hint that life may have originated in space by revealing that the exposed samples contained substances similar to nucleosides, the sub-unit of nucleic acids, which had apparently been stimulated by their exposure to direct sunlight. Medusa experiments continued through the Salyut programme.

Ivanchenkov then floated outside and attached the Yakor (Anchor) device at the left hand side of the hatch. He reported that it held firm as the station drifted out of radio contact with FCC.

The complex entered the shadow of Earth at about 0425 GMT. According to one analyst, the men erected portable lamps to work in the nighttime portion of the orbit but switched them off so that they could view the stars and lights on the Earth's surface. They reportedly could see lights from ships and, at one point near to sunrise, saw the five-second-long bright trail of a nearby meteor as it flashed by the station. Kovalenok missed the opportunity to photograph the spectacular event.

A TV camera was fixed to Salyut's hatch. Contact with FCC was resumed at 0502, just at sunrise. The first TV pictures were returned shortly afterwards showing Ivanchenkov floating against the backdrop of the blue and white of Earth. The men returned TV pictures of the areas of the station where they had removed the sample packages and showed new cassettes they had attached.

At one point Kovalenok described the work as "very agitated. . . difficult, but interesting."

Kovalenok's heart rate was measured as 105 beats per minute whilst his partner's registered 95.

In the 54 minutes of daylight during their second "day" the men checked features of the complex relating to movement outside. They also installed a special device to record the background cosmic radiation.

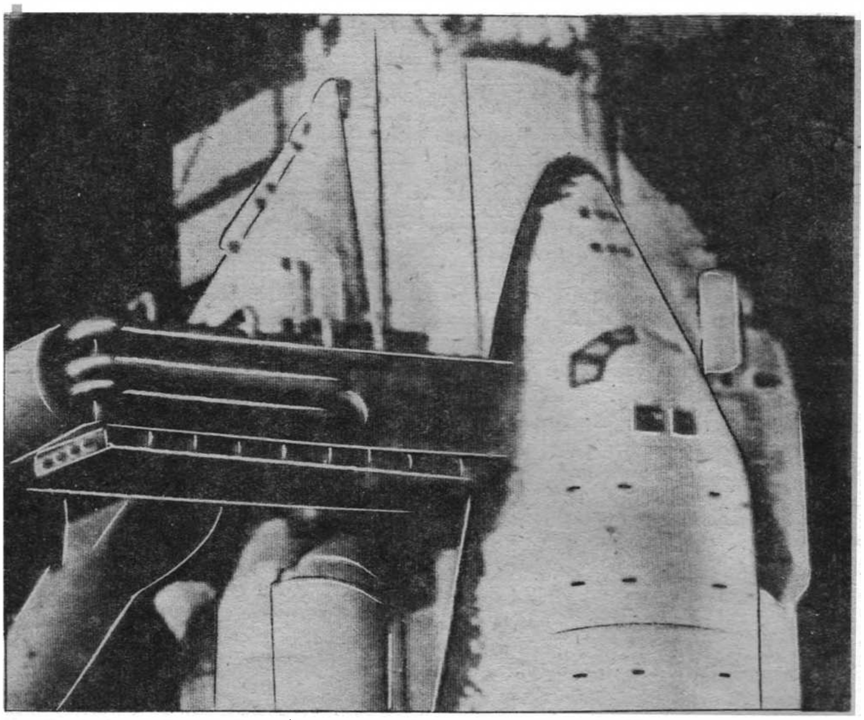
The men completed their work earlier than planned and were told to return to Salyut by FCC. However, Kovalenok declined saying that "we would just like to take our time, because it is the first time in 45 days that we have been out of doors for a walk."

The complex entered Earth's shadow again at about 0556 GMT and about 4 minutes later the men closed the hatch to return to Salyut and the rest of their mission.

The second EVA from Salyut 6 had lasted 2 hours and 5 minutes.

This major feature on Soviet EVA operations continues in the next edition of *Spaceflight*.

The Soviet Snowstorm; Winged Wonder or White Elephant?



The Soviet Space Shuttle Buran (Snowstorm). Is the latest addition to the Soviet Union's space fleet 'a costly mistake'?

By Peter R. Bond

On 15 November, the Soviet Space Shuttle Buran (Snowstorm) completed a triumphant maiden flight after two orbits of the Earth. President Gorbachev described this event as opening up "a qualitatively new stage in the Soviet space research programme". Only a week later, this "outstanding achievement of Soviet cosmonautics" was thoroughly debunked by one of the Soviet Union's leading space scientists. Glasnost strikes again!

Academician Roald Sagdeyev is the retiring director of the Space Research Institute in Moscow. He has been the leading light in the Soviet drive towards international co-operation in the peaceful exploration of space, an initiative which clearly has the backing of the Soviet government. However, he has become increasingly outspoken in recent months, openly condemning the "poor discipline among mission controllers" which led to the disablement of the Phobos 1 spacecraft, and actively promoting the election of former dissident Andrei Sakharov to the Presidium of the USSR Academy of Sciences.

In an article written to coincide with the visit of these two scientists to the USA, Mr. Sagdeyev condemned the American and Soviet Shuttles as having "absolutely no scientific value". He went on to write that the Shuttle was "an outstanding technological achievement" but a costly mistake "We have put too much emphasis on manned flight at the expense of unmanned efforts that produce more scientific information at lower cost." Is this just another case of sour grapes from an individual who sees his particular area of specialisation starved of funds while another, supposedly less worthwhile, area of scientific endeavour receives an abundance of cash and political support?

Sagdeyev condemned the American and Soviet Shuttles as having "absolutely no scientific value". He went on to write that the Shuttle was "an outstanding technological achievement" but a costly mistake.

The question of the relative efficiency and cost-effectiveness of manned exploration of the Solar System versus exploration by unmanned probes has existed for decades Is it really necessary to spend a fortune on sending people into space when 'intelligent' robots could be used at a fraction of the cost and at no risk to human life?

This debate was particularly strident in the 60's and early 70's when the Soviets were singing the praises of their robot lunar explorers at a time when huge sums of American taxpayers' money were being spent on sending men to the Moon and returning them safely to Earth An explosion on Apollo 13 nearly stranded three astronauts in space, and only marvellous improvisation, combined with the good fortune that the lunar module was still attached, saved the crew from a lingering death

Yet many supporters of manned flights were quick to counter that no robot could make decisions and value judgements like the human brain. On numerous occasions, human ingenuity has saved an experiment which would otherwise have been doomed. Apollo astronauts were able to select unusual or striking rock samples in a way not open to robot craft Furthermore, the astronauts brought home a vast haul of lunar rocks weighing 385 kg compared with the tiny handfuls returned by automatic Luna craft.

Despite using technology which has often been described as primitive or outdated, Soviet scientists have regularly and successfully put automatic systems into operation in space The first automatic docking of two unmanned spacecraft, Cosmos 186 and 188, took place as long ago as 1967. Since then, heavy Cosmos modules, including the Kvant astrophysical module, and 39 Progress supply craft have docked automatically with Soviet space stations. The Soviets have made much of the fact that Buran's first flight was also conducted automatically, a feat never accomplished by the American Shuttle.

The Soviet Shuttle incorporates several other safety factors compared with its American counterpart. The US version was originally intended to fly with liquid fuel boosters rather than the Solid Rocket Boosters (SRB's) which resulted in the calamitous explosion of Challenger in 1986. SRB's are cheaper and easier to manufacture since they do not need the complex internal plumbing of liquid motors. However, they have the big disadvantage that, like fireworks, they cannot be extinguished or throttled back once ignition has begun. The Soviets have designed Buran to fly piggy-back on the liquid-fuelled Energia, the world's most powerful launcher. In the event of a problem with one of the engines on Energia, it can automatically be shut down, enabling Buran to abort to orbit or return for an emergency landing.

The cost-effectiveness of the Soviet system is improved by Energia's flexibility. As

well as providing the propulsion for Shuttle launches, the giant booster can be used to place payloads of more than 100 tonnes in low Earth orbit or 18 tonnes in geostationary orbit, and used to send craft weighing 32 tonnes to the Moon or 28 tonnes to Mars and Venus. This capability and flexibility are the envy of every other spacefaring nation. Furthermore, the Soviets have designed Energia to be at least partially reusable. The four first stage boosters fall away in pairs and parachute back to Earth ready for refuelling and further use, while the core stage splashes down in the Pacific.

So why is Academician Sagdeyev complaining? Soviet officials have admitted that the Energia-Buran system has taken ten years to develop and has cost some $10 billion – approximately the same as the American Shuttle. Although they have obviously been helped by American pioneering research – some Western authorities, including the Pentagon, claim that Buran is almost a straight copy of the American Shuttle – nine design bureaus are thought to have been involved in this major programme, swallowing up capital and resources which could have been used in other areas.

Meanwhile, even before the replacement for Challenger is wheeled out onto the runway, the American space agency NASA is looking forward to safer, more efficient launch vehicles, such as the unmanned Shuttle-C (***Spaceflight***, November 1988 p. 412). The American military have already shown their disenchantment with the Shuttle by ordering a fleet of expendable launch vehicles. It is now clear that the Shuttle will never be a financial success as a satellite launcher, and that it will continue to be a drain on the NASA budget for years to come, filtering off funds which could be directed towards the Freedom space station and the once-proud Solar System exploration programme. Clearly Mr. Sagdeyev believes the same thing is happening in the Soviet Union.

The US vehicle was originally intended to act as a shuttle craft carrying crews and cargo to and from an orbiting space station. Budgetary constraints, political opposition and public apathy led to the cancellation of the successor to Skylab. The Soviets already have their permanently manned space station, Mir, and intend to orbit a much larger version in the 1990's which will be constructed using the Energia-Buran system. Meanwhile, specialised research modules will be added to the existing station until it grows to a formidable 135 tonne structure. However, the Soviet Shuttle is apparently not intended as a regular supply craft for the space stations.

Glavkosmos chairman Alexander Dunayev has disclosed that several reusable Shuttles are under construction, and that they should be operational for "decades". However, he went on to emphasise that Shuttles would only carry spacecraft or orbit in exceptional cases since an Energia-Buran launch costs tens of times more than a launch by existing conventional carrier rockets. Dunayev also disclosed that no more than two to four Shuttle flights a year are envisaged. These comments have been reinforced by Vladimir Shatalov, chief of cosmonaut training: "Considering that the USSR plans to continue using all types of rockets, Buran-type craft aren't expected to fly very often." So why build a Shuttle craft?

Roald Sagdeyev

The desire to update hardware must be one motive. The existing fleet of expendable boosters annually launches more than 100 payloads into orbit, far more than all other nations put together. These dependable workhorses and variations of the three-man Soyuz ferry have served the Soviets well for the past 20 years, but any self-respecting space power which is eager to project the image of a thriving, modern post-industrial country cannot be expected to rely for ever on outdated technology.

"Considering that the USSR plans to continue using all types of rockets, Buran-type craft aren't expected to fly very often." So why build a shuttle craft ?

Once the argument for safer, more modern manned spacecraft is won, the discussion then turns to what you can do with the new creation. Early official statements vaguely mentioned "orbiting some large-scale but fragile loads, repairs out in space or bringing back to Earth satellites that have developed faults". As in the US version, a "manipulator" in the cargo bay is available for releasing or placing satellites in the bay. Such opportunities for satellite repair work at an altitude of 250 km are fairly limited since many satellites orbit Earth at much greater altitudes.

On the other hand, Buran's capability to carry a 30 tonne payload into low Earth orbit (considerably more than the US version) or to return a 20 tonne load (equivalent to a heavy Cosmos research module or the entire Mir base unit) back to Earth has obvious advantages. The orbiter can also be used for the Soviet equivalent of a Shuttle-Spacelab mission, lasting up to a month in low orbit.

Recent Soviet pronouncements have been more specific about the future operations of their Shuttle. Chief Designer Reusable Spaceships, Yuri Semenov, has announced that Buran will one day retrieve the mothballed Salyut 7 and return it to Earth for inspection. However, its main mission is to "launch costly facilities fitted out with unique scientific instruments, for example, large optical telescopes with sophisticated electronic equipment". Other uses could include "the creation in orbit of big radio telescopes, aerial systems, solar power stations and interplanetary complexes. These are extremely expensive constructions, each of which is the only one of its kind and needs to be serviced by manipulators, robots and qualified personnel". Such large constructions could one day include a 450 tonne craft for a manned Mars expedition. But do such specialised functions really justify massive expenditure on a Shuttle craft?

What about transfer of crews to and from the space station? Shatalov admits that it makes more sense to use the usual Soyuz system to carry two or three men into orbit. However, Buran is designed to dock with Mir, and is capable of carrying up to 10 crew, including "experimenters and researchers". This description implies that science specialists will play an increasing part in future crews visiting Mir, replacing the military test pilots who have so far dominated the cosmonaut corps.

Mir is capable of receiving four more scientific laboratories similar to Kvant, and, from Soviet statements, these modules clearly have an important role to play in the coming years, despite delays in their development. They will include facilities for micro-gravity processing of materials, for Earth-resources investigation, and astrophysical observations. Certainly, a flight on board the Shuttle should be less stressful for older, relatively unfit scientists, particularly during re-entry, than on the cramped Soyuz capsule. Researchers will also be able to bring back more samples and equipment than is currently possible in the cramped Soyuz TM.

Mikhail Gorbachev expressed his hopes and ambitions for the new craft shortly after Buran's safe return: the Shuttle "makes it possible to concentrate the principal efforts and means in those areas of space exploration that will ensure the maximum economic return to the national economy and will advance science towards higher frontiers". Is this brave rhetoric simply an echo of the words so proudly spoken by President Reagan after the American Shuttle's maiden flight in 1981?

Academician Sagdeyev clearly disagrees with his political master. Comparing the space programmes of the two superpowers in an unflattering light, he wrote: "The US aerospace industry, like the Soviet industry bureaucracies, used its influence to subvert the logic of science." He is not alone. Academician Vladimir Struminsky is of the opinion that Buran is less cost-efficient for ferrying cargoes to orbit and retrieving them than traditional spacecraft. Energia designer Boris Gubanov has admitted that the booster's payload-takeoff weight ratio can be quite low, mainly due to the problem of ensuring extra safety measures for Shuttle crews.

Professor Sagdeyev speaks for many space scientists all over the world, not least in the United States where years of expertise in planetary exploration have been squandered during a decade of inactivity. Is his pessimism justified? Is the Soviet Snowstorm a winged wonder or a white elephant? No doubt readers of ***Spaceflight*** have their options on this matter. Only time will tell.

BOOK NOTICES

RACE INTO SPACE: The Soviet Space Programme

B. Harvey, J. Wiley & Sons Ltd., Baffins Lane, Chichester, W. Sussex, England, PO19 1UD, 1988, 381pp, £16.95.

In this account the author describes the awe and astonishment widely felt when the first Sputnik circled the Earth and which, he believes will continue to inspire further generations of scientists and technologists.

The dramatic events of the Soviet Space Programme are recounted from its earliest beginnings, starting with the theoreticians of the 19th century whose ideas culminated in the Sputnik launches in 1955–57. Gagarin's epic single-orbit flight is dealt with in detail as well as the many ensuing pioneer manned spaceflights, including the flight of Valentina Tereschkova, the first woman to venture into space.

USSR-US rivalry in the race to the Moon is described, followed by an account of Soviet Space Centres which contains much which will be new to many readers.

Soviet deep space missions, so successful in flights to Venus, achieved patchwork results when applied to Mars, though such mishaps were more than outweighed by the extensive manned space flights over a number of years involving the Salyut and Mir Space Stations and record-duration stays by cosmonauts.

It remains a mystery to many in Europe and elsewhere why a country such as the USSR should invest so much material resources in the conquest of space when it faces major difficulties in agricultural production and in meeting consumer needs generally . The factors that led the USSR into space in the 1950s undoubtedly had little to do with space clairvoyants The drive for military supremacy and the desire to demonstrate technological prowess were undoubtedly the real factors that provided the initial will to put men into space and send the first rockets to other worlds.

By the late 1970s, Russian cosmonauts were flying in space for half a year at a time and a decade later the Soviets were operating a permanent space station in orbit where modules were docked together, reformed and refuelled though, ironically, these years of solid achievement have been virtually unnoticed outside the USSR itself.

Even so, much previous Soviet space history remains unclear e.g. the story of how the Soviet lunar plans evolved, changed, and ultimately collapsed. There is also little about possible earlier space stations and even the history of the Soviet Space Shuttle remains obscure.

This book endeavours to record and assess all these events and to place them into perspective.

As the author remarks, *"The race into space may now be over: the conquest of the solar system could be about to begin"*.

The Soviet Manned Space Programme

P. Clark, Salamander Books, 52 Bedford Row, London, WC1R 4LR, 1988, 192pp, £14.95.

This book evolved from papers originally prepared by the author and Ralph Gibbons for publication in the Journal of the British Interplanetary Society and is dedicated to the memory of Anthony Kendon (1947–1987) a former Fellow of the Society.

The USSR Space Programme continually evokes surprise at the realization of size and vitality of both their manned and unmanned programmes, including launch vehicle lift capacity and the rapidly extending number of man-hours logged.

This superbly illustrated book describes the origin of this ambitious programme, the rivalries with America that spurred Soviet designers in the 1960's and the evolving strategy behind the manned missions that have led to the dominant position of the USSR in such missions today.

The book also looks ahead to the forthcoming Soviet Shuttle and to the, even larger, permanently manned space station complexes as well and, ultimately, to a manned Mars Mission.

The Soviet Space Programme

R D. Humble, Routledge, Chapman & Hall Ltd., 11 New Fetter Lane, London, EC4P 4EE, 1988, 158pp, £30.00.

Although the USSR Space Programme has been impressive and embraced a number of projects and activities ahead of the Amercians, until very recently the Soviets have been unduly secretive about many aspects, even those of a non-military character.

This book endeavours to redress the balance by providing an overview of Soviet Space programmes from the beginning to the present time, an important theme emphasised being the substantial degree to which it has been orientated towards military purposes.

Guide to Manned Space Missions

C. Van Den Berg, Jr, Gemini Productions Holland, Fuustraat 10, 3362 NC Sliedrecht, The Netherlands. 1988, 131pp, £7.95.

This book, based on the use of a computer database, provides an account of all manned space flights between 1961-88, including the thirteen X-15 rocket-aircraft missions which exceeded an altitude of 80 km, the height often regarded as the demarkation line between air and space. Also listed are all who were trained or selected for future or cancelled missions but who never actually ventured into space.

The volume is divided into three major parts – Manned Space Programmes, Manned Space Missions and details of astronauts and cosmonauts in various formats. All material is presented in tabular form, each table beginning with a section which explains the column numbering.

Webb Society Deep-Sky Observer's Handbook Vol.6 (Anonoymous Galaxies)

Ed. K.G. Jones, Enslow Publishers Inc., P O Box 38 Aldershot, Hants, GU12 6BP. 1987, 160pp £10.95.

Webb Society Deep-Sky Observer's Handbook Vol. 7 (The Southern Sky)

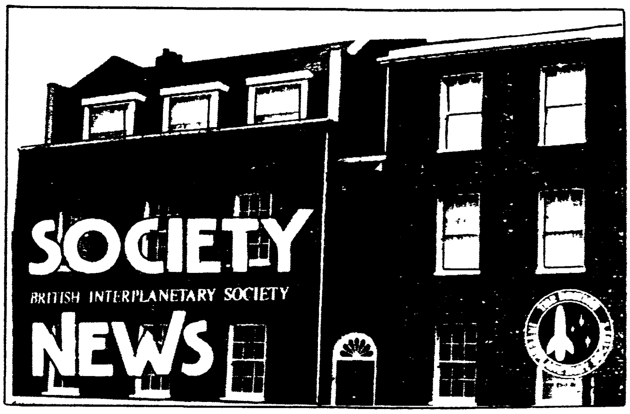
Ed K.G. Jones, Enslow Publishers Inc., P O Box 38, Aldershot, Hants, GU12 6BP. 1987, 228pp, £14.95.

Both of these belong to a series of independent volumes addressed to the more serious amateur astronomer, the series title commemorating the Reverend T. W. Webb (1807-1885), an eminent amateur astronomer who authored the classic work *"Celestial Objects for Common Telescopes"*, first published in 1859. Each volume is complete and self-contained with respect to the subject covered.

Anonymous galaxies, i.e. objects not listed even in the comprehensive New General Catalogue and its two index supplements, are dealt with in Vol.6. After a brief historical review, the book describes the older visual catalogues and the many modern photographic catalogues and atlases upon which any search for anonymous galaxies must be based. Following chapters indicate the methods required to observe such faint and remote objects, for advances in telescope making in recent years now make it possible for an amateur to be the first to observe and describe one of them. The second part of the book contains a catalogue which details, with diagrams, observations of 165 galaxies. Actually, many are listed in specialised catalogues but some really are "unlisted" and thus, hitherto truly anonymous, for which their particular observers may now claim right of discovery.

Whereas earlier volumes were confined to areas of the sky north of about 20 degrees S.decl., Vol.7 describes some of the glittering prizes to be seen only from the southern hemisphere. It starts with a short history of observations of the southern sky, followed by extended descriptions of a dozen or so major celestial objects. The major part then catalogues and illutrates some 300 other important objects, though rather briefly.

An idea of the riches accumulated south of, say, 30 degrees S.decl i.e. comprising only one quarter of the total celestial sphere, can be gauged from the fact that it includes the centre of our galaxy, the "Coal-sack" - that most prominent of the great clouds of interstellar dust, the Magellanic Clouds, planetary and diffuse nebulae in abundance and both open and closed star clusters. All this without the attraction of the Southern Cross and Alpha Centauri.



Society in Good Shape for 1989

The Society enters 1989 with the green light showing for an effective programme of activities. Much of this is made possible by the continuing support of members and others who support the Society in its role of promoting the advancement of space and astronautics.

1988 saw important new developments in space with a continuing close involvement by the Society and many of its members, either through the Society or on an individual basis.

Robert H. Oakes of Gosport, Hants writes:

> I should like to take this opportunity to congratulate all those involved with the running of our Society and on the excellence of its publications, which must be the finest available in this country Well done! In addition I would like to express my appreciation of the continuing efforts to publicize and advance both manned and unmanned astronautics by our Society's executive members – especially in the light of the political climate that exists in our country at the present time

1988 was also a time of considerable upheaval at the Society's HQ due to the renovation of the premises, both externally and internally (***Spaceflight***, January 1988, p.31). Work is continuing on the building's interior and, although much still remains to be done, it is clear that the attendant benefits to our programme will be showing through in 1989.

News . . . Society News . . . Society

The Society fulfils an international role through its world-wide membership and by virtue of its position as the UK National Representative Body of the International Astronautical Federation (IAF). As part of this work the Society will be co-sponsoring the IAF International Conference on Space Power to be held in June 1989 and the 8th International Space Development Conference to held in Chicago in May 1989.

In addition the Society is co-sponsoring an Institute of Electrical Engineers (IEE) meeting on Electric Propulsion.

Details of these events will appear in the Meetings Diary.

The Society will continue to keep readers up-to-date with news and views of developments in space by its ***Spaceflight*** magazine, which has world-wide distribution. Overseas copies will continue to be dispatched by air-speed delivery.

Detailed technical material will continue to be published in JBIS for which several special issues are planned during 1989. The technical work of the Society will also be carried forward through its meetings programme and, for those members who are at a distance and not able to attend, reports of meetings and of the papers presented will be published wherever practicable.

'Join Now for 1989'

Joining the BIS means becoming part of a world-wide membership for promoting space and astronautics. Founded in 1933, the BIS has been to the fore from the early pioneering days of interplanetary concepts to the dramatic space accomplishments of the present day.

The BIS continues to look towards the future, as it has done in previous years, realising that progress depends on energetic and broad-based support for the development of new and peaceful space initiatives and the advancement of relevant knowledge. Membership of the Society is an effective way of providing such support and of advancing space and astronautics internationally.

At this time of the year members are asked to make a special effort to bring the work of the Society to the attention of colleagues and others and to invite them to "Join Now for 1989". A copy of ***Spaceflight*** will be sent by the Society, free-of-charge, to any friend or colleague nominated. Please write to the Society with appropriate names and addresses.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Subject to space being available members may also apply for a ticket for one guest.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

1 February 1989, 7.00-8.30 p.m. Lecture

THE DAWN OF THE SPACE AGE

A lecture by Dr. John Becklake. The space age began on October 4 with the launch of Sputnik 1. This was the culmination of a sequence of events dating from the start of the 20th Century.

Admission is by ticket only. Members should apply in good time by enclosing a stamped addressed envelope.

March 1 1989, 7.00-8.30 p.m. Lecture

SOME INTERESTING SPACE PIONEERS

This lecture by Professor Ian Smith reviews the contribution made by a number of noted space pioneers known to the speaker, including Wernher von Braun and Val Cleaver.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

8 March 1988, 2.00-5.00pm Colloquium

ELECTRIC PROPULSION COLLOQUIUM

A meeting co-sponsored by the British Interplanetary Society and the Institute of Electrical Engineers. The primary aim of the meeting is to discuss the applications of Electric Propulsion, not the technology itself.

For more information please write to the Executive Secretary, 27/29 South Lambeth Road, London, SW8 1SZ.

3 June 1989 10am-4.30pm Symposium

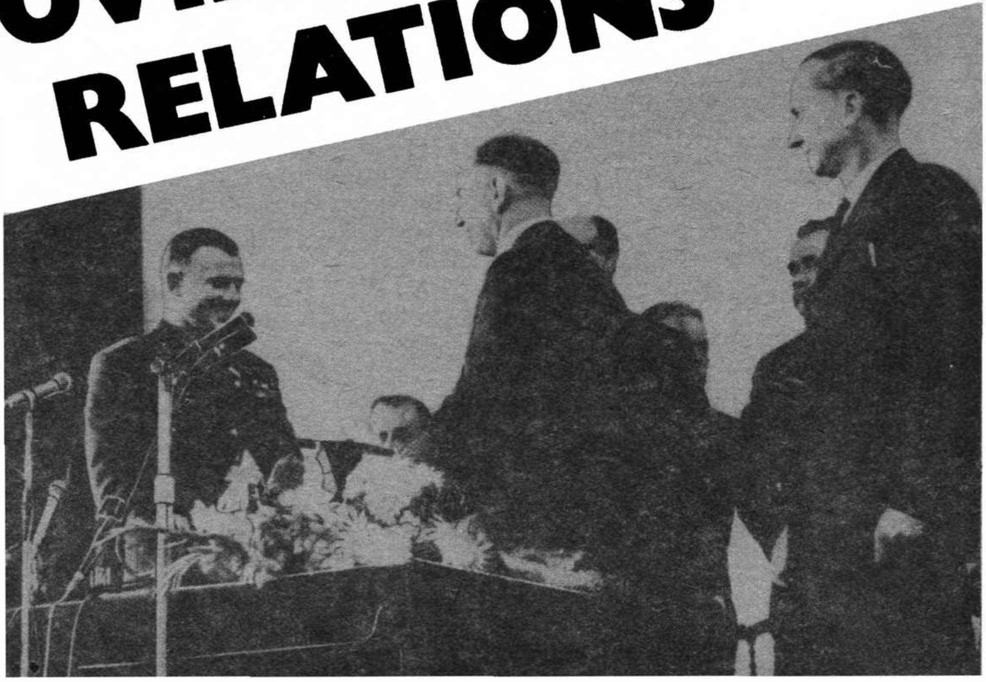
SOVIET ASTRONAUTICS

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

BIS-SOVIET RELATIONS



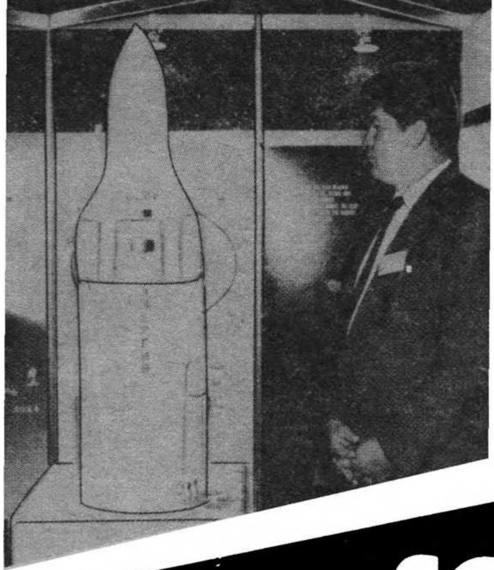
Dr W R Maxwell, with other representatives of the Society, presents its Gold Medal to Yuri Gagarin during his visit to London in 1961

First Man in Space Honoured by Presentation of BIS Gold Medal

The medal is three inches in diameter and bears the presentation inscription on one side, in this case to Yuri Gagarin

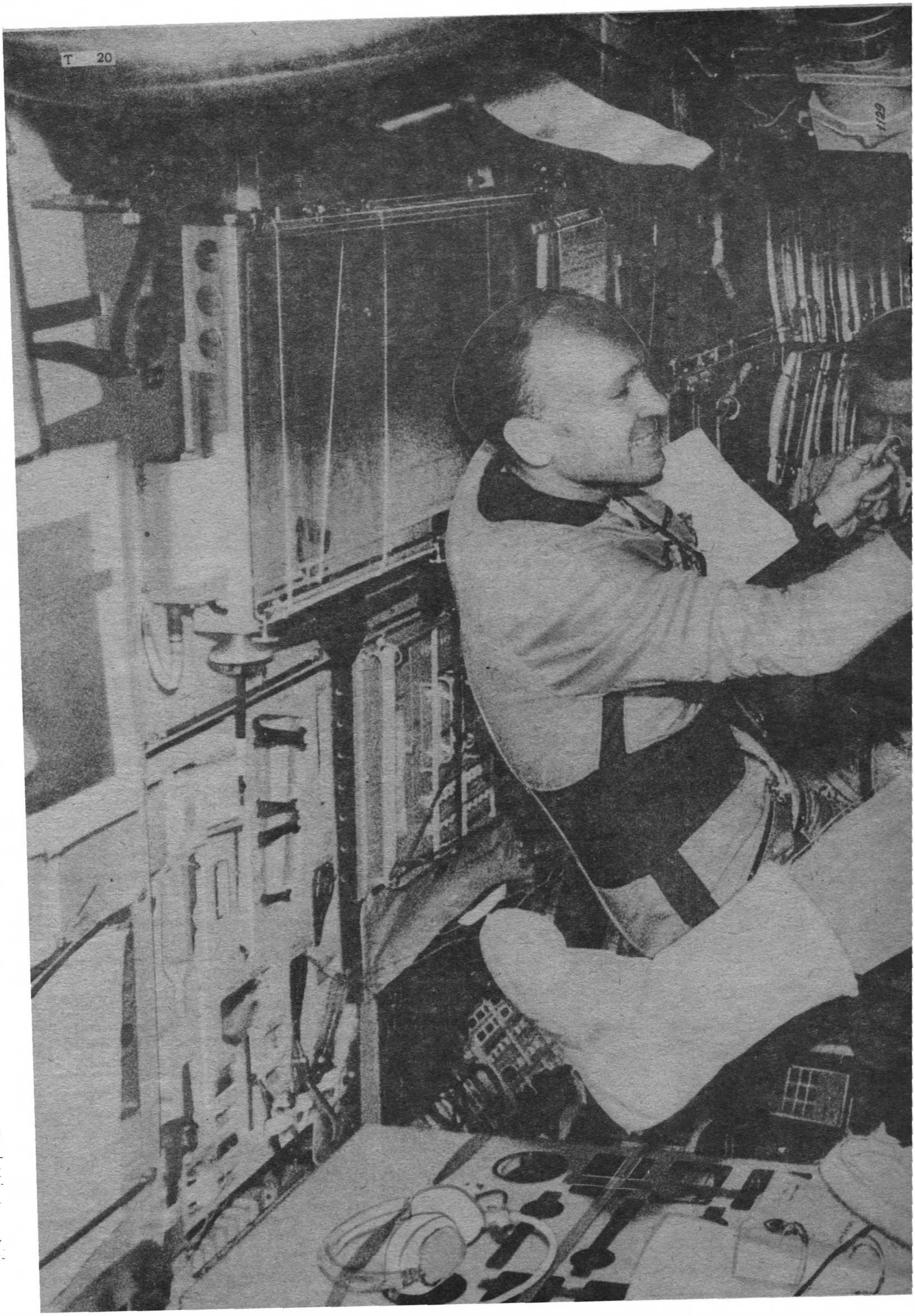
ENERGIA Model First Shown at BIS' SPACE '87

Cosmonaut Valeri Ryumin and the Energia model at SPACE '87, Brighton. *P. J. Fulford*



Pull-Out Poster

SOVIETS in SPACE

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Spaceflight
February 1989
Published by
The British Interplanetary Society
27/29 South Lambeth Road
London, SW8 1SZ, England

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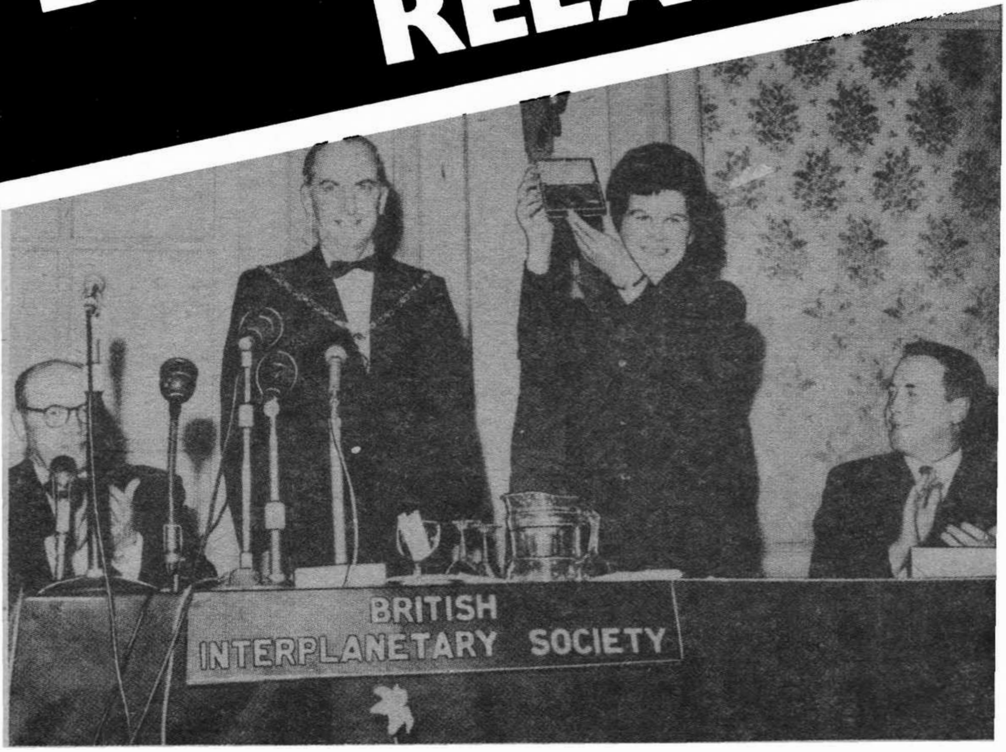
BIS-SOVIET RELATIONS

First Woman in Space Honoured by Presentation of BIS Gold Medal



Valentina Tereshkova receives the Society's Gold Medal in recognition of her historic flight in Vostok 6 during a visit to London at the invitation of the BIS The presentation was made by Dr L R. Shepherd at a special meeting of the Society at the Piccadilly Hotel, London.

The other side of the medal bears a motif comprising of the world, a space rocket and a human figure

BIS 50th Anniversary Honoured by 'Intercosmos' Council of the USSR Academy of Sciences

АКАДЕМИЯ НАУК СССР
СОВЕТ ПО МЕЖДУНАРОДНОМУ СОТРУДНИЧЕСТВУ
В ОБЛАСТИ ИССЛЕДОВАНИЯ И ИСПОЛЬЗОВАНИЯ КОСМИЧЕСКОГО ПРОСТРАНСТВА
«ИНТЕРКОСМОС»

ACADEMY OF SCIENCES OF THE USSR
COUNCIL ON INTERNATIONAL
COOPERATION IN RESEARCH AND USES OF OUTER SPACE
«INTERCOSMOS»

[illegible] Tel. [illegible]

1 ноября 1983г. № 10240/1137

L J Carter
Executive Secretary
27/29 South Lambeth Road
London SW8 ISZ
England

Уважаемый господин Картер,

Совет "Интеркосмос" при АН СССР шлет Британскому обществу межпланетных сообщений поздравления в связи с 50-летием его деятельности и наилучшие пожелания. Мы ценим большой вклад Общества в развитие космонавтики в мирных целях на благо человечества и в информирование общественности о космических достижениях.

С уважением,

Председатель Совета
"Интеркосмос" при Академии наук
СССР
академик В.А.Котельников

The translation reads:

Dear Mr. Carter,

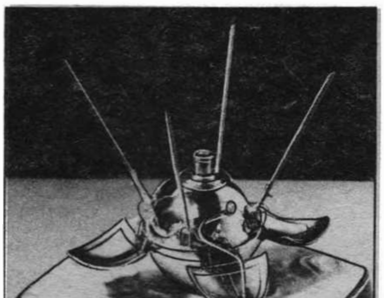
The "Intercosmos" Council of the USSR Academy of Sciences sends its congratulations and best wishes to the British Interplanetary Society on the occasion of the 50th Anniversary of its activity. We appreciate the great contribution of the Society to the development of cosmonautics of peaceful aims for the welfare of humanity and to the (task of) informing the public about space achievements.

Yours respectfully,

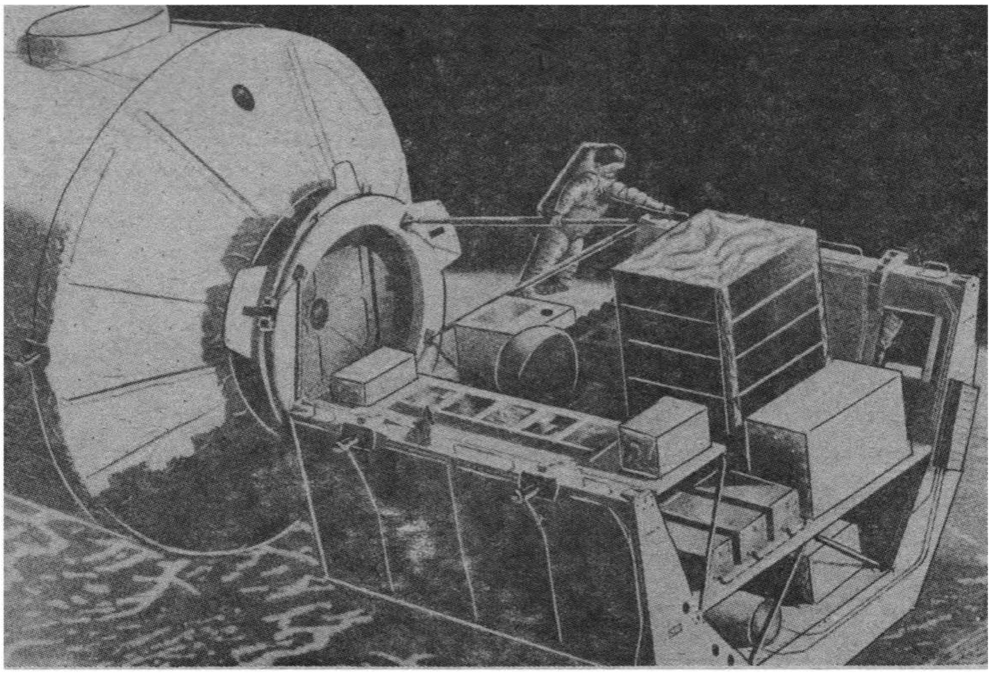
Academician V.A. KOTELNIKOU
Chairman of the "Intercosmos" Council
of the USSR Academy of Sciences

Poster:
Cosmonauts, Valentin Lebedev, Anatoli Berezovoi and Svetlana Savitskaya relax onboard the Salyut 7 space station in 1982.

First Successful Lunar Soft Landing by Luna 9



On July 13, 1966, at a special meeting of the Society at University College London, Dr L R Shepherd presented this silver model of Luna 9 to Academician A. A Blagonravov representing the USSR Academy of Sciences to mark the first soft landing on the Moon on February 3, 1966



A pallet attached to the Columbus Attached Pressurised Laboratory acting as an exposed experiment platform, a concept outlined in a British Aerospace paper at the symposium.

Expanding the Space Infrastructure

The following Report on the one-day symposium held by the Society on November 15, 1988 is provided by *Mark Hempsell*:

By 'Space Infrastructure' is meant the collection of those working elements which provide the supporting functions to space activity. Included are such systems as launch vehicles, space stations, lunar bases and planetary transportation systems, all analogous to roads, railways, power utilities and the like of our terrestrial infrastructure.

It was, therefore, very timely that the Society should have held a symposium on this subject on November 15, 1988, the same day that the Soviet Union successfully tested a major new element in their own space infrastructures.

Eight papers were presented ranging from the long-term future of space infrastructures to detailed proposals for systems able to support the next step.

The day started with Bob Parkinson outlining work on models for the space economy appropriate to the middle of the next century. This gave, in impressive detail, the likely economic interaction of bases and colonies throughout the Solar System, from the Moon to Jupiter. The major exports of this economy to Earth would come from solar power satellites, microgravity processing products and tourism in low-Earth orbit, all for a postulated population of around 25,000 people with a gross space product of 16 billion 1986 dollars.

The next paper from Mark Hempsell built on this work by describing a programme for expanding the current space infrastructure to the size indicated by the Parkinson model. It estimated a time-scale of at least 45 years after establishing the space station to build up colonies and bases of the size indicated by the model. It suggested also that the infrastructure described might provide the minimum needed to meet the requirements of an expanding industrial-based civilisation in the 21st century.

John Sved also explored the broad thrust of expansion into space, in particular the drive to establish a lunar colony, drawing a series of striking comparisons with the British colonization of Australia.

Two following papers, by Uwe Riedel and Klaus-Peter Ludwig from MBB/ERNO, gave an overview of infrastructure studies funded by ESA, the German Government and internally by the company. Most significant in the short term was a study for ESA called "Long-Term Evolution Toward European Manned Spaceflight", which outlined development of an independent European Space Station and which had been followed up by a series of more detailed studies that will, hopefully, lead to such a station in the first decade of the next century.

Other studies took a more long-term view, including an interesting re-examination of solar power satellites in the light of technology improvements since the last major examination in the mid 1970s. As might be expected the increasing number of studies now being conducted in support of decision-makers at all levels in Germany starkly contrasts with the situation in the United Kingdom.

Gerry Webb and P. Hansson of Commercial Space Technologies Ltd, presented a joint paper on the subject of exploiting the resources of the Martian moons, Phobos and Deimos. The theme was finding the easiest source of materials to supply the major space industries needed to maintain a technology-based civilization. The audience was reminded of the oft-forgotten fact that it takes less energy to reach the Martian moons than it does to reach the lunar surface. The paper suggested some of the materials that could be returned, with particular emphasis on platinum and related metals.

The day finished with two papers on several detailed matters. Mark Hempsell and Charles Martin of British Aeorspace presented a joint paper showing the potential use of the Spacelab Pallets as exposed platforms on the Freedom space station while Dave Salt discussed details of transportation between the space station and lunar facilities, showing the impact of various locations on launch window, flight times and velocity.

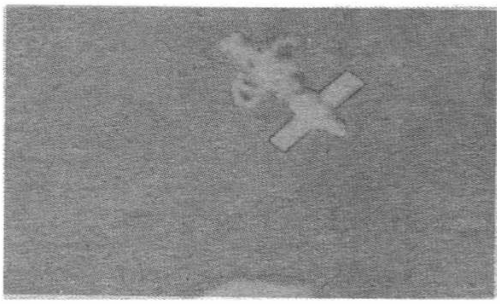
Almost half the papers made reference to the work of Tony Martin who delivered a paper at SPACE '84 on the need of space resources to prevent the collapse of a technology-based civilization over the next two centuries. It was therefore appropriate that he was in the audience and started off a lively and wide-ranging discussion on our need for space infrastructures.

Soviet Spacecraft Revealed

Sir, Whilst at the recent Soviet space exhibition in Birmingham I saw two videos and managed to snap some shots of two vehicles which have not, to my knowledge, been seen in the west.

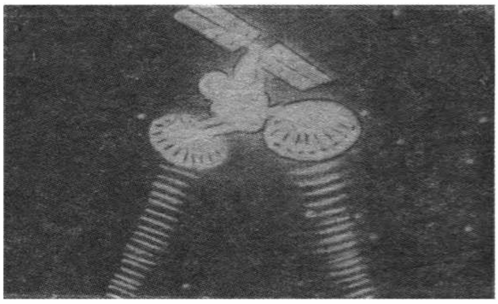
The two vehicles are:

Kosmos 1686. This appears in a long-range shot taken by the departing Soyuz T-15 crewmen. Not much is evident of the actual structure but we can see that it has solar panels, it is attached to the front of Salyut 7, and has a "stunted" appearance. The Soviets said that this Heavy Kosmos module did not carry a return vehicle as did the Kosmos 1443 vehicle. Therefore, until better shots are available, we must conclude that the front contains a battery of telescopes.



Salyut 7 and Kosmos 1686 taken from Soyuz T-15.

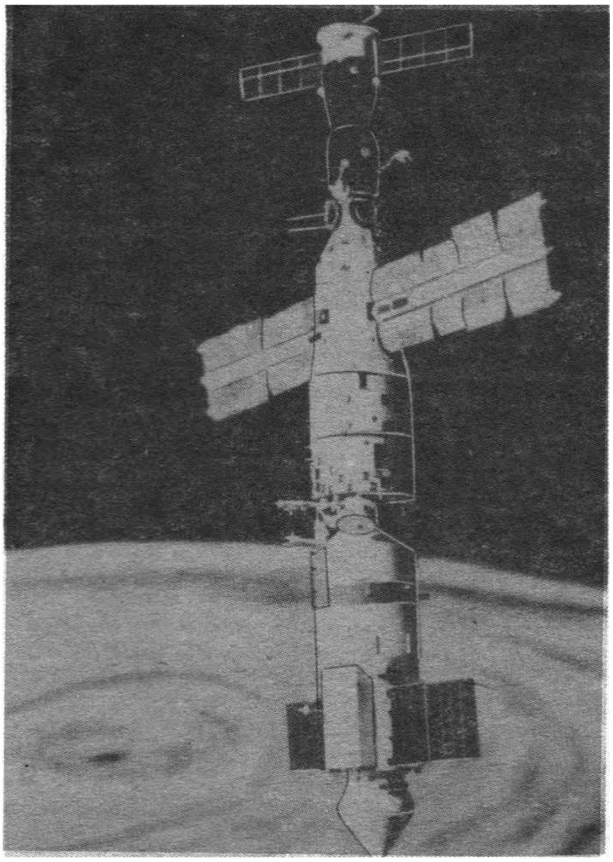
Luch. This is the film's rendition of the Kosmos 1700 Luch SDRN relay satellite in geostationary orbit. It carries two large antennas for receiving transmissions from Mir and for relaying these to the ground. Two solar panels atop the box-and-cylindrical structure provide power to the electronics.



Luch (Kosmos 1700) illustration.

Finally, I have enclosed a photo of a model made by Phil Mills of the Kvant Functional Assembly Block constructed on the basis of Soviet drawings. The FAB, which served as the engine block for the delivery of the Kvant astrophysics module was left in orbit after detaching from the Mir complex. The extra firings of its engines to achieve the rendezvous and docking with Mir in April 1987 meant that it was left with insufficient fuel for a controlled reentry and it burned up on 25 August.

NEVILLE KIDGER
Morley, Leeds, UK



Model by Phil Mills of the Kvant/Mir complex before the Kvant FAB was detached on April 12, 1987.

Soyuz Orbital Module

Sir, With reference to the letters in ***Spaceflight*** (June and August 1988) concerning the Soyuz TM Orbital Module.

In view of the problems encountered by Vladimir Lyakhov and Abdul Ahad Mohmand aboard Soyuz TM-5 returning to Earth in September I would have thought the module's use was obvious. It is simply provided above all else to give the crew more room. It will be recalled that the cosmonauts spent an uncomfortable 24 hours in the cramped Soyuz Descent Module prior to their delayed return to Earth.

Moreover, since that flight several cosmonauts and Soviet space officials have commented that the orbital module might be retained longer after undocking from Mir prior to reentry. It will be interesting if this procedure is changed for future flights.

Keep up the good work at ***Spaceflight***.

GEORGE A. SPITERI
Birmingham, UK

Energia

Sir, Further to Mr. Lawton's letter in November ***Spaceflight***, p.438, we have now seen numerous pictures of Energia in combination with the Soviet shuttle Buran.

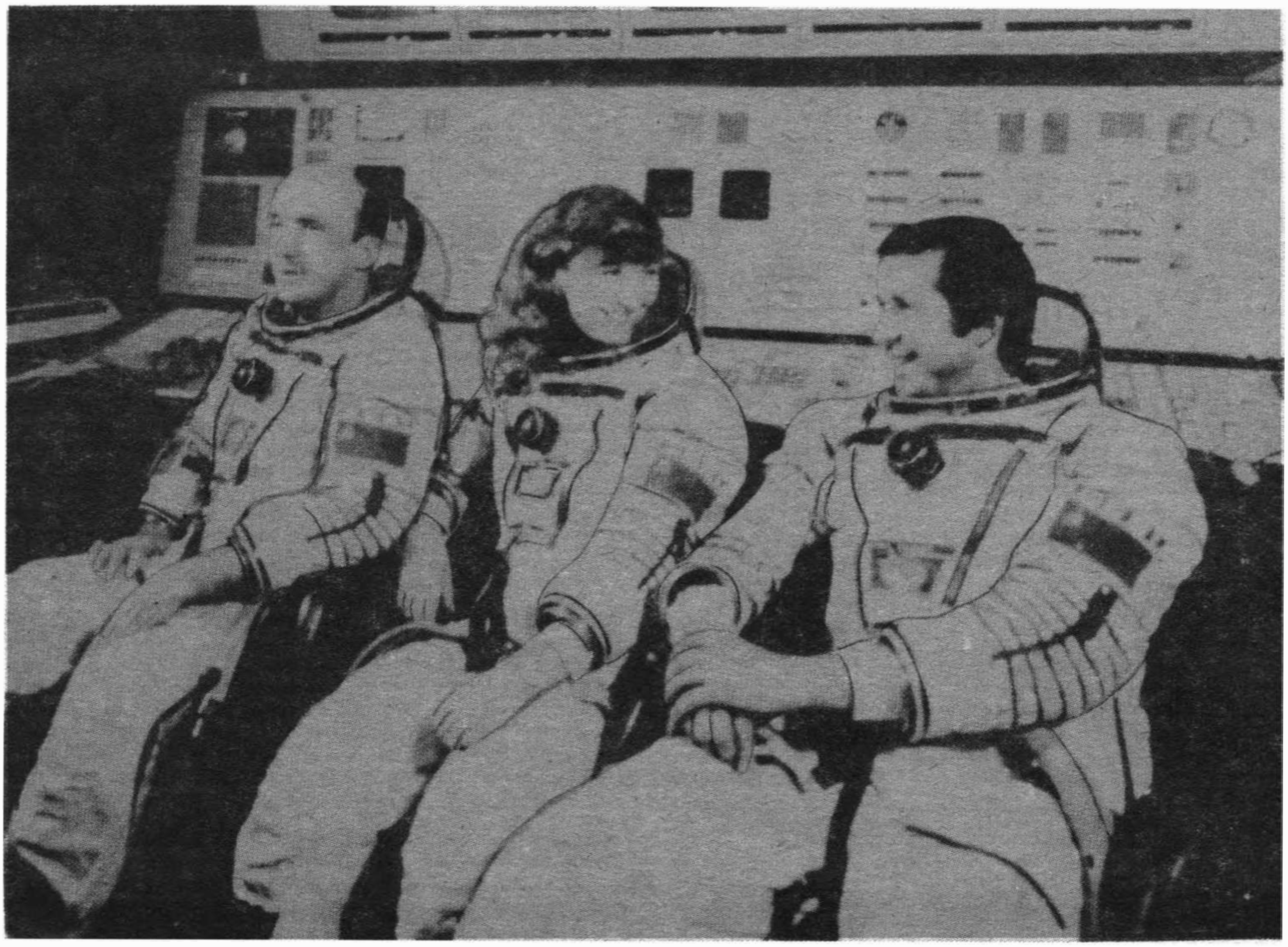
The length of Buran, given as 36 metres, is consistent with the height of Energia given as 60 metres. But in this case the diameter of Energia's core is hardly much less than 8.5 metres, not 8 as stated.

The height/width ratio of the "Brighton model" of Energia is not correct.

The core diameter makes a greater difference to the estimated size of Energia than the height, since the volume varies as the square of the diameter. Taking the core diameter as 8.5 metres makes Energia one-eigth bigger than if it was 8 metres – no small consideration.

TONY DEVEREUX
Essex, UK

CORRESPONDENCE SOVIETS in SPACE



The back-up crew of Soyuz T-7. Left to right: V.V. Vasyutin, Irina Pronina and V.P. Savinykh. It is understood that Irina Pronina may be assigned to a Mir mission in 1991.

Soviet Backup List

Sir, Enclosed is a list of back up crews to Soviet missions which I received recently from the information group in Zvezdny Gorodok. It solves some longstanding mysteries like the names of the Soyuz–13 back ups and the name of the back up flight engineer of Soyuz–24. All in all, it contained six new names. I'm sure the list will be of interest.

Valery Aleksandrovich Yazdovsky was born on July 8, 1930. He joined the cosmonaut team in November 1969 and left in December 1973 (the month Soyuz 13, for which he was the back up flight engineer, was launched).

Lev Vasilyevich Vorobyov was born on February 24, 1931. He became a cosmonaut in October 1963 and left in June 1974. Michail Ivanovich Lisun was born on September 5, 1935, and became a cosmonaut in October 1965. He is said to be still active.

Vladimir Sergeyevich Kozelsky was born on January 12, 1942 and selected in May 1967. He too is still active.

Vladimir Yevenyevich Preobrazhensky was born on February 3, 1939 and was selected in October 1965. He left the team in October 1980.

Yekaterina Aleksandrovna Ivanova was born in 1949. She became a cosmonaut in 1980. Another member of this selection was Irina Rudolfovna Pronina who was born on April 14, 1953. Both are still active.

Vostok–1	Titov G S.
Vostok–2	Nikolayev A.G.
Vostok–3	Bykovsky V.F Volynov B.V
Vostok–4	Komarov V M Volynov B.V.
Vostok–5	Volynov B V
Vostok–6	Solovyova I.B. Ponomareva V.L.
Voskhod–1	Volynov B V. Katys G P. Lazarev V G.
Voskhod–2	Gorbatko V.V. Zaikin D A. Khrunov Y.V.
Soyuz–1	Gagarin Y.A.
Soyuz–3	Shatalov V.A. Volynov B.V.
Soyuz–4	Shonin G.S.
Soyuz–5	Filipchenko A.V Kubasov V.N. Gorbatko V V.
Soyuz–6	Shatalov V.A. Yeliseyev A.S.
Soyuz–7	Shatalov V.A. Kolodin P.I Yeliseyev A.S
Soyuz–8	Nikolayev A.G. Sevastyanov V.I.
Soyuz–9	Filipchenko A.V. Grechko G.M. Lazarev V G. Yazdovsky V.A.
Soyuz–10	Leonov A.A. Kubasov G.M. Kolodin G.I. Dobrovolsky G.T. Volkov V.N. Patsayev V.I
Soyuz–11	Leonov A.A. Kubasov V.N. Kolodin G.I.
Soyuz–12	Gubarev A.A. Grechko G.M.
Soyuz–13	Vorobyov L.B. Yazdovsky V.A.
Soyuz–14	Sarafanov G.M. Demin L.S. Volynov B.V Zholobov V.M. Zudov V.D. Rozhdestvensky V.I
Soyuz–15	Volynov B V Zholobov V.M. Zudov V.D. Rozhdestvensky V I.
Soyuz–16	Dzhanibekov V.A. Andreyev B.D. Romanenko Y.B. Ivanchenkov A.S.
Soyuz–17	Lazarev V.G. Makarov O.G. Klimuk P.I. Sevastyanov V.I.

CORRESPONDENCE

Soyuz–18	Kovalyonok V.V. Ponomaryov Y.A.
Soyuz–19	Filipchenko A.V. Rukavishnikov N.N. Romanenko Y.V. Ivanchenkov A.S. Dzhanibekov V.A. Andreyev B.D.
Soyuz–21	Zudov V.D. Rozhdestvensky V.I. Gorbatko V.V. Glazkov Y.N. Berezovoi A.N. Lisun M.I.
Soyuz–22	Malyshev Y.V. Strekalov G.M. Popov L.I. Andreyev B D.
Soyuz–23	Gorbatko V.V. Glazkov Y.N. Berezovoi A.N Lisun M.I.
Soyuz–24	Berezovoi A.N. Lisun M.I. Kozelsky V.S. Preobrazhensky V.E.
Soyuz–25	Romanenko Y.V. Ivanchenkov A.S.
Soyuz–26	Kovalyonok V.V Ivanchenkov A.S.
Soyuz–27	Kovalyonok V V. Ivanchenkov A.S.
Soyuz–28	Rukavishnikov N N. Pelcak O.
Soyuz–29	Lyakhov V.A. Ryumin V.V.
Soyuz–30	Kubasov V N. Jankowski Z.
Soyuz–31	Gorbatko V V. Kollner E.
Soyuz–32	Popov L.I. Lebedev V V.
Soyuz–33	Romanenko Y.V. Aleksandrov A.P.
Soyuz–35	Zudov V.D. Andreyev B.D.
Soyuz–36	Dzhanibekov V.A. Magyari B.
Soyuz T–2	Kizim L.D. Makarov O.G.
Soyuz–37	Bykovsky V F. Liem B.T.
Soyuz–38	Khrunov Y.V. Lopez-Falcon J A.
Soyuz T–3	Lazarev V.G. Savinykh V.P. Polyakov V V.
Soyuz T–4	Zudov V.D. Andreyev B.D.
Soyuz–39	Lyakhov V.A. Ganzorig M.
Soyuz–40	Romanenko Y.V. Dediu D.
Soyuz T–5	Titov V.G. Strekalov G.M.
Soyuz T–6	Kizim L.D. Solovyov V.A. Baudry P.
Soyuz T–7	Vasyutin V.V. Savinykh V.P. Pronina I.R.*
Soyuz T–8	Lyakhov V.A. Savinykh V.P. Aleksandrov A.P.
Soyuz T–9	Titov V.G. Strekalov G.M.
Soyuz T–10	Vasyutin V.V. Savinykh V.P. Polyakov V.V.
Soyuz T–11	Berezovoi A.N. Grechko G.M. Malhotra R.
Soyuz T–12	Vasyutin V.V. Savinykh V.P. Ivanova E.A.
Soyuz T–13	Popov L.I. Aleksandrov A.P.
Soyuz T–14	Viktorenko A.S. Strekalov G.M. Saley Y.V.**
Soyuz T–15	Viktorenko A.S. Aleksandrov A.P.
Soyuz TM–2	Titov V.G. Serebrov A.A.
Soyuz TM–3	Solovyov A.Y. Savinykh V.P. Habib M.
Soyuz TM–4	Volkov A.A. Kaleri A.Y. Shchukin A.V.
Soyuz TM–5	Lyakhov V.A. Serebrov A.A. Stoyanov K.

* Irina Rudolfovna Pronina was born on April 14, 1953
** Yevgeny Vladimirovich Saley was born on January 1, 1950.

BERT VIS
Den Haag, The Netherlands

Soviet Back-up Crews

Sir, My reaction to ***Spaceflight*** is belated because of the slow distribution of the magazine in the Soviet Union.

In ***Spaceflight***, March 1988, p.115, Neville Kidger assumed that Aleksandr Shchukin was in the same group as Levchenko. He is incorrect. Comrade Maltsev from the Cosmonaut Training Centre informed me about the biographical data of Shchukin. Aleksandr Shchukin joined the cosmonaut team in 1982 (Volk and Levchenko were in 1978). Readers might be interested to learn that Shchukin was born on January 19, 1946 in Vienna, Austria.

In correspondence, ***Spaceflight***, February 1988, p.72, Anne van den Berg linked Dr Ilyuin with the Voskhod 1 mission. This is wrong. In April 1988 our military newspaper *Krasnaya Zvezda* revealed that seven men were trained for this space flight: Two pilots (V. Komarov and B. Volynov), two engineers (K. Feoktistov, G. Katys) and three physicians (V. Lararev, A. Sorokin, B. Yegorov).

Georgi Katys and Alexi Sorokin have been unknown for a very long time. I recently received photographs of these two men from the Cosmonaut Training Centre.

Georgi Katys

Alexei Sorokin

Anne van de Berg suggested that Viktorenko must have been the Soyuz 13 back-up commander, with Sevastyanov being the back-up flight engineer. This is also wrong. In *Aviatsiya i Kosmonavtika* no. 6, 1988 (p.44–45) Viktorenko revealed that in May 1977 A. Nikolayev visited Viktorenko's aircraft unit of the Baltic Fleet for cosmonaut selection. He wrote; "After medical tests I and N. Grekov were selected to join the cosmonaut team." So he was not at the Cosmonaut Training Centre until after the Soyuz 13 mission.

I can say that the Soyuz 13 back-ups were both space rookies and were to have been the prime crew but were replaced by Kilmuk and Lebedev.

Women Cosmonaut Crew Revealed

There has been much speculation and assumptions made in the space press about a Soviet all-woman crew.

I recently asked comrade S.M. Yegupov, an employee of the Cosmonaut Training Centre, about the crew. He informed me that the all-woman crew that trained for a Salyut-7 mission was:

- Svetlana Yevgenyevna Savitskaya
- Yekaterina Aleksandrovna Ivanova
- Yelena Ivanovna Dobrokvashina

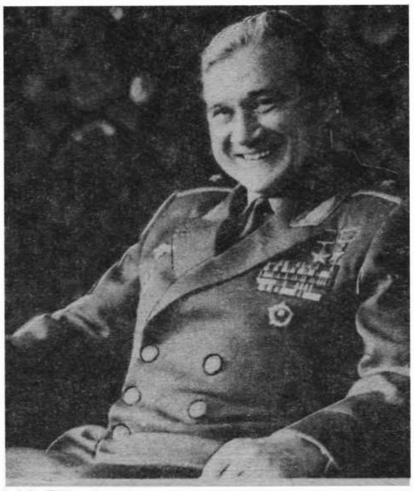
I hope this information is of interest to your readers.

VADIM Y. MOLCHANOV
Tula, USSR

Ed. *Since receiving this letter we have learnt of the sad death of Aleksandr Shuchukin in an aircraft accident on August 18, 1988.*

Y.P. Artyukhin

G.T. Dobrovolski



A.V. Filipchenko

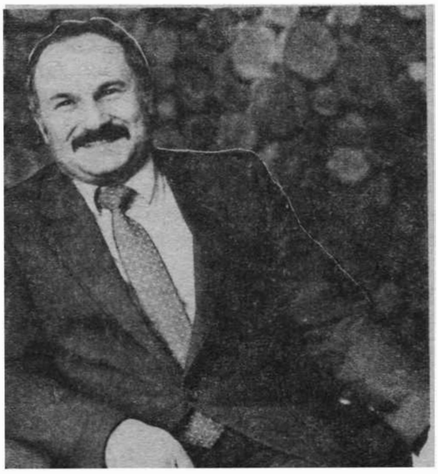
Cosmonauts of 1963

Sir, Recently the Cosmonaut Training Centre sent to me the list of cosmonauts selected in 1963. Readers may be interested to learn their names.

1. Yuri Petrovich ARTYUKHIN
2. Eduard Ivanovich BUINOVSKI
3. Georg Timoteyevich DOBROVOLSKI
4. Lev Stepanovich DYOMIN
5. Anatoli Vasilyevich FILIPCHENKO
6. Aleksey Aleksandrovich GUBAREV
7. Vladislav Ivanovich GULYAYEV
8. Pyotr Ivanovich KOLODIN
9. Eduard Pavlovich KUGNO
10. Anatoli Petrovich KUKLIN
11. Aleksandr Nikolayevich MATNICHENKO
12. Vladimir Aleksandrovich SHATALOV
13. Lev Vasilyevich VOROBYOV
14. Anatoli Fyodorovich VORONOV
15. Vitali Mikhailovich ZHOLOBOV

Seven of them became real cosmonauts. Two others were in back-up crews – Kolodin was the RE on the Soyuz 7, 10, 11 and Vorobyov was the CDR on the Soyuz 13, so six men were left out.

VADIM Y. MOLCHANOV
Tula, USSR



V.M. Zholobov

V.A. Shatalov

A.A. Gubarev

A Visit to Baikonur

Sir, You may be interested in the following facts that emerged from a visit to the Baikonur Cosmodrome.

The next module to be launched to the Mir space station will be a 20-ton Mir class spacecraft, providing additional life support systems and a large EVA airlock with a one metre diameter airlock.

The module will carry the first Soviet MMU. This will be tested by cosmonaut Alexander Volkov but only inside the module.

The MMU will be flown first by Alexander Serebrov, the flight engineer of Soyuz TM8 which will be launched in late April to replace the Volkov-Krikalev-Polyakov crew. Serebrov's commander will be Alexander Viktorenko and, if France agrees to pay for a commercial mission, the third crewmember could be Chretien's back up Michel Tognini. All three make up the back up crew of Soyuz TM7.

The Soviet space shuttle ejector seat is based on the Mig 25 and can be used from the launch pad to up to a speed of Mach 3. It can also be used for speeds below Mach 3 during landing and even on the runway if necessary.

Energia's core stage is not recovered and there are no plans to recover it. Its strap-on stages are not recovered either but there are plans to do so in future, with parachutes, soft landing rockets or a combination of both. The "packs" seen on the side of the strap-ons on the first two Energias are merely simulated parachute/engine containers.

The next flight of the Soviet shuttle will be unmanned and

an extended mission. The third flight will be manned by two test pilots but probably not until 1990.

Tyuratam, the name of the railway junction near to which the "Baikonur Cosmodrome" was developed, is derived from Tyura Tam – the burial place of Tyura, a son of Jenghis Khan.

The name of Baikonur was chosen for the cosmodrome in 1961 because, needing to give Gagarin's launch site in order for his flight to be properly ratified, a flustered engineer chose Baikonur because in Russian it means "rich region", which to him sounded better than "burial place."

It has been formerly confirmed by General Kerim Kerimov, Soviet president of the state commission for manned spaceflight, that the original Soyuz 11 crew was indeed, Alexei Leonov, Valeri Kubasov and Pyotr Kolodin and they were replaced en masse by the back up crew when a medical inspection showed up a spot on Kubasov's lung. This was the final medical inspection before Kerimov was to formally announce the crew a few days before lift off so Leonov and company became the so far, only total crew to be replaced so close to lift off. Kerimov had toyed with the idea of just replacing Kubasov but felt it was too late.

TIM FURNISS
Bideford, Devon, UK

A Second Soviet Spaceplane?

Sir, Many indications [1] have appeared that the Soviets are developing one or more small but highly manoeuvrable spaceplanes with an aerodynamic shape quite different from the much larger Buran, the Soviet counterpart to the US Space Shuttle. It is, therfore, safe to assume that their planned role in the Soviet space programme is also quite different.

Although the general name "Kosmolyot" (Russian term for 'spaceplane') had often been used to describe these craft, I prefer the name 'Albatros' to distinguish a specific machine whose main characteristics resemble those of its natural counterpart, defined as "a large bird with a powerful gliding flight capable of spending long periods away from land".

Reports suggest that a small manned spaceplane is to begin full-scale testing as part of a programme to run separately from but in parallel with, the continuing (Buran) shuttle programme, and is intended for defence purposes, reconaissance work and the emergency repair of large Soviet satellites. The machine is expected to be operational in 1990. Its launch vehicle is the new SL-16 booster which has flown successfully seven times up to June 1987.

The SL-16M 'Albatros' launcher and the SL-16 Kosmos 1786 launcher are possibly recoverable. Testing the first stage recovery system [3] would seem to have been the object of the initial sub-orbital trials of Kosmos 1697 and 1714. Less than two months separated these trials so it may be concluded that certain aspects of the recovery system had to be fully proved in this first phase. It is, therefore, likely that these two firings were of the same equipment, providing information on typical turn-around times (51 days), the behaviour of their first recoverable booster and how the actual recovery and refurbishment programme met the design requirements.

Kosmos 1767 was the first true orbital vehicle, achieving a nominal orbit of 250 km apogee and 190 km perigee. It was presumed successful. Kosmos 1786 had exceptional orbital elements and is interesting for its apogee, given as 2,560 km. This figure, confirmed by Goddard Space Center, probably represents an extra impulse added by a motored dummy payload, after the style of the first 'Energia' launch.

This could be a Soviet test of an SL-16 launcher carrying a "dumb" but motored upper stage, i.e. and 'Albatros'-type payload. The Kosmos 1786 orbit could be indicative of the wide range of orbital choices available to the spaceplane needed to fill its projected role. The payload itself would have been a complete dummy, correct in mass, thrust, and mass ratio, but lacking aerodynamic characteristics.

The SL-16 launch programme has been very rapid (2 years) and apparently highly successful.

Ref. 4 mentioned the probability of a spaceplane design (Kosmolyot I) intended for use with the Proton SL-13 launch vehicle. Early sketches of Kosmolyot I show it to bear a strong resemblence to the abandoned Boeing X-20 'Dynasoar' project. A full size 'Dynasoar' would have been launched by Titan, a close counterpart of Proton. This scheme foundered when the launch vehicle did not receive man-rating. A new but similar launch vehicle, inherently safer and with a sturdier structure, has been realised in the newly emerged SL-16.

The extra programme taken by the launch vehicle development was also used to refine the Kosmolyot design as a result of flight testing an experimental scale model, which I have provisionally called 'Mischka', to arrive at Kosmolyot II. 'Mischka' showed that the earier ideas similar to Dynasoar have been considerably modified. The wings have a very sharp dihedral of approximately 45 degrees, a vertical fin has been added, the fuselage has been fattened, and a carefully contoured nose included in what appears to be a sophisticated craft intended to explore manoevrability and control over a very wide velocity range.

The outlines of "Mischka" bear a strong resemblance to the very successful Martin X-24B flown during the early and mid 1970's.

"Mischka" clearly shows a configuration expected for 'Albatros', but a significant question is – "what scale does Mischka represent?". Scaling factors on hypersonic aircraft are not simple: a minor instability in a model may be more of major importance on a full-sized man-carrying craft.

Western analysts are not agreed on the scale factor involved between 'Mischka' and the full-sized 'Albatros'. The US Department of Defence considers it to be a ⅓ scale model [5], others a ¼ scale [1]. The latter seems to produce too large a vehicle for 15 tonnes total weight and also may be stretching modelling scale dynamic factors too far. A scaling factor of 2.75 between 'Mischka' and 'Albatros' would give rise to a conservative design.

DOD consider that for 15 tonnes all-up weight 'Albatros' will have a wing span of 9.4 metres, a length of 16.25 metres and a fuselage depth of approximately 3.0 metres. This would comfortably fit on top of an SL-16 lift vehicle but the weight seems optimistically light for the quoted dimensions.

Using its single large manueovring engine, 'Albatros' would skim the upper atmosphere at a height of 80 km (50 miles). After high-resolution surveillance has been completed, the motor would be turned on to give the velocity increment needed to allow the spacecraft to do an orbital rendezvous with a spacestation complex.

A spaceplane like this would be capable of being lifted into LEO, docking with a space complex and performing various upper atmosphere tasks before returning to be refuelled and serviced. After a space duration of say 6 months or so, it would return to Earth base for checks. When these are completed 'Albatros' is placed atop an SL-16 and sent into orbit for a further 6 months mission.

When it does finally achieve operational status it will *complement*, not replace the existing Soyuz craft.

A.T. LAWTON
Goring, Sussex, UK

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2 P. S Clark, 'The Medium Lift Booster', ***JBIS***, March 1988, pp 117–124
3 A T Lawton, 'Energia, Soviet Super Rocket', ***Spaceflight***, August 1987, pp 285–289
4 A T Lawton, 'The Soviet Space Shuttle Programme', ***Spaceflight***, Supplement No 1, July 1987, pp 4–7
5 'Soviet Military Power', 1983 and 1984 editions, US Department of Defence

CORRESPONDENCE

Space Shuttles

Sir, In comparing the American and Soviet shuttles it is perhaps worth pointing out that the Soviet decision to locate the main engines on the external fuel tank, rather than on the shuttle body (and thus condemning them to destruction when the tank is discarded) has perhaps proved a wiser decision.

NASA originally planned that their main engines would be reuseable almost infinitely – with a minimum life of (at the very least) fifty flights. Technology has proved once again difficult to master, and in fact the space shuttle main engines are lucky to survive ten flights, with only one exceptionally well built motor – serial number 2012 – having made fifteen.

With mass production being cheaper than individual refurbishment, the Soviets have taken advantage of NASA's problems and made a decision which in the long term can only be more cost effective and which certainly provides greater reliability.

R. A. FLOOD
Darmstadt
West Germany

Space Elevator

Sir, Congratulations on the excellent article on "Space Tethers," by Rodica Ionasescu and Paul Penzo. The article gives me an opportunity to correct one misconception that most tether researchers have about the origin of the space elevator concept.

Tsiolkovsky did not invent the space elevator. His 1896 thought experiment envisioned a "cosmic railway" above the atmosphere and helped him understand the reversal of gravity on a tall tower, but it was not a workable device, any more than Einstein's famous "gedankenexperiment" on the equivalence of gravity and inertia in an elevator in space envisioned a real structure.

The first person to propose a real elevator was the Leningrad engineer Yuri Artsutanov [1]. In 1960, he proposed a large, passenger-carrying tower between the equator and a geostationary satellite and recognized some unusual energy aspects of the space elevator not seen by Tsiolkovsky. He did not publish a technical paper, however, and his work was not known in the West in 1966, when Isaacs *et al.* re-invented the space elevator on a small scale [2]. They proposed "walking" small payloads into orbit by alternately raising and lowering two fine wires balanced about the geostationary point. This paper also received very little notice.

The third, and last, invention of the space elevator was my "orbital tower," conceived in 1970 and published in 1975 [3]. This concept is, like Artsutanov's, a large-scale, passenger-carrying device. I also proposed the re-capture of the energy of returning payloads to power other payloads into orbit, thus requiring almost zero net energy input. A recent paper [4] summarises these and more recent concepts for building elevators into space.

After the wide dissemination of my Acta Astronautica article, the concept became well known; there will likely be no more lonely discoverers of the space elevator. The important point is that Tsiolkovsky's work was simply a thought experiment, the credit for the first invention of the space elevator rightly belongs to Yuri Artsutanov.

JEROME PEARSON
Ohio, USA

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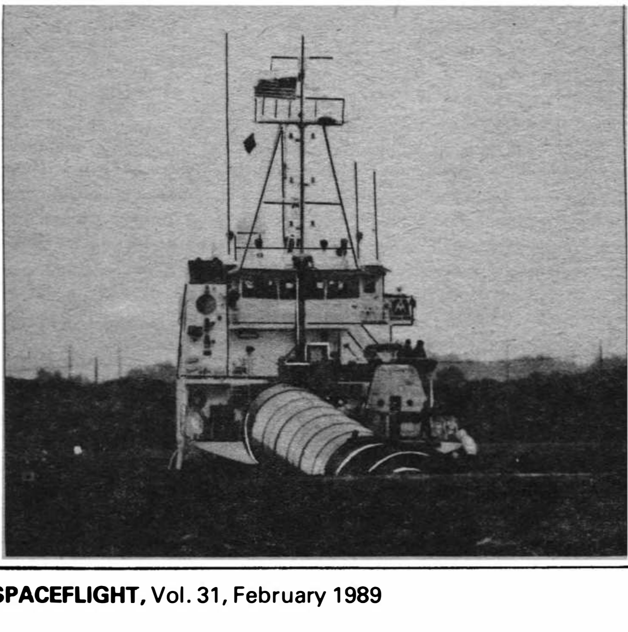
Gherman Titov, the second man to orbit the Earth and the youngest man in space at the age of 25 in August 1961, photographed recently by Tim Furniss at Baikonur. *Tim Furniss*

SRB Recovery

Sir, I took the enclosed picture from the Jetty Park at Port Canaveral, Florida on September 30, 1988 using a 500mm lens. It shows the right hand Solid Rocket Booster being towed into Port Canaveral after the STS-26 launch of Discovery. The booster frustrum is seen on the fantail of the recovery vessel, the Liberty Star.

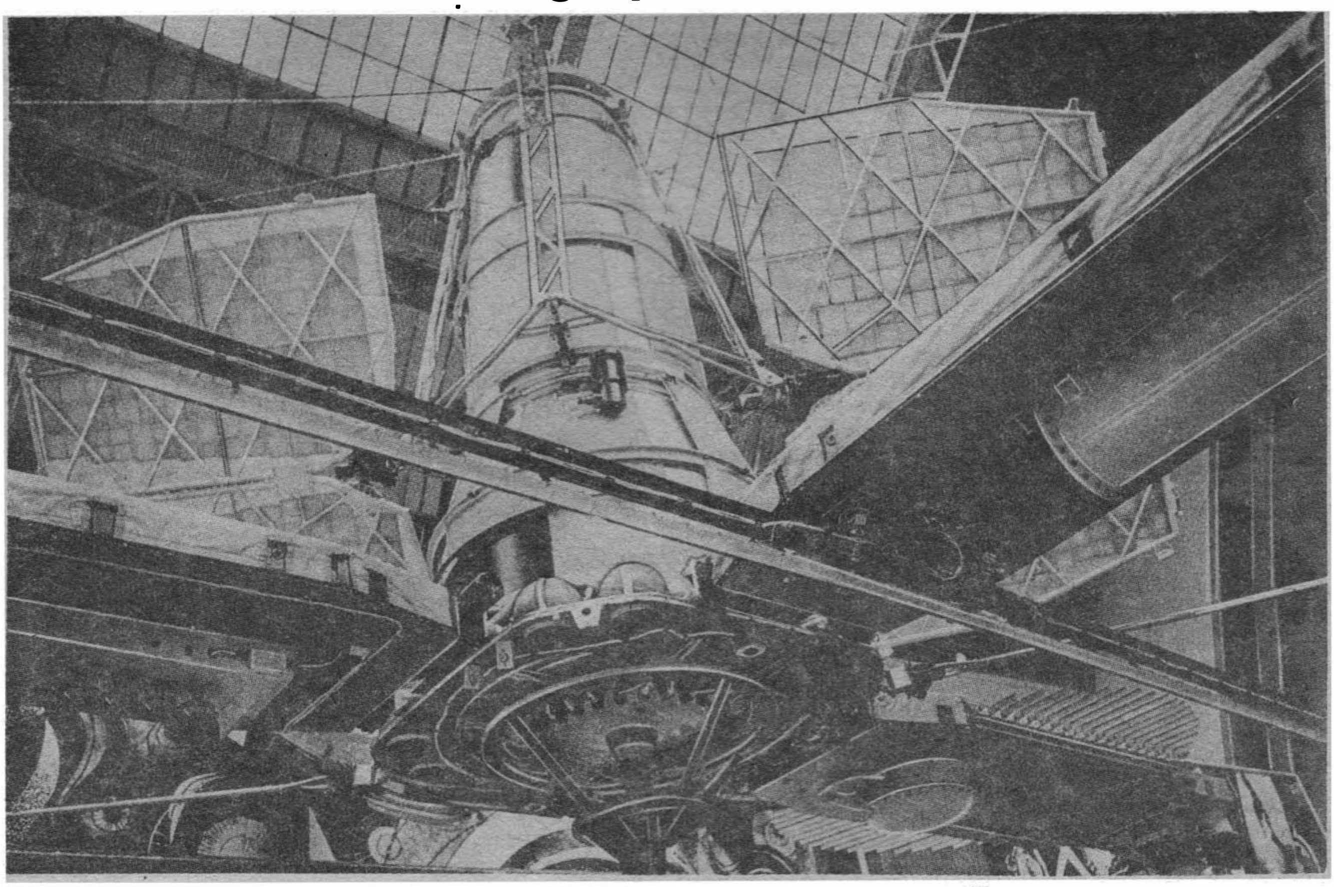
JOEL W. POWELL
Calgary, Alberta, Canada

On the day after the launch of Discovery the skies are overcast as a recovered SRB is towed into port *Joel W Powell*



A New Eye on the Seas

Soviet Oceanographic Satellite System



The central cone of Okean. Four panels are attached to the lower structure, with downward-pointing instruments. Upper surfaces have mustard colour surround to reflect the Sun's rays. *Brian Harvey*

On July 5, 1988 the Soviet Union announced that it had established an operational space system for the observation of our planet's seas and water surfaces. A new designation, Okean (ocean) was issued to mark the series. In fact, the Soviet Union has flown operational oceanographic missions for five years under the Cosmos series. These missions are part of an impressive level of Soviet commitment to Earth resources and space applications work.

Cosmos 1500, orbited in September 1983, was a new and distinct operational design of a Cosmos satellite. It was a truncated cone with four long and large vanes where downward-looking observation instruments were mounted. Sun-seeking solar panels were attached to the upper cone. Spacecraft weight has been estimated at 1,600 kg, but the working model recently displayed in Moscow suggests it mav be much more. This new design was first mooted by NORAD in 1986 [1] but the Cosmos 1500 design was not made public until later. At around this time, the USSR revealed that the

By Brian Harvey

Cosmos 1500 model had been tested twice before 1983 [2].

These preoperational missions were Cosmos 1076 and Cosmos 1151, of February 1979 and January 1980 respectively. Both satellites – and the subsequent operational missions – went into orbits typical of electronic intelligence (ELINT) satellites – 82.5 deg flying out of Plesetsk. In fact, were it not for an oceanographic role being ascribed to them, it would have been hard to identify them from standard ELINT missions. All have come out of Plesetsk northern cosmodrome, probably on the Cyclone rocket, though some accounts have suggested the A2 and even the C1 booster [3].

These two preoperational flights took place at the same time as the United States was developing advanced oceanographic techniques. SEASAT went into a 805 km orbit in June 1978 and until that October it provided spectacular vistas of sea conditions around the globe.

Description of the Series

No full account of the series was published until Cosmos 1500 was returning good data. It was announced that the series was intended to cover the world's oceans in a three-day phase, with special attention being paid to the Arctic and Antarctic. The former is of considerable economic importance to the Soviet Union, where cargoes must be shipped along Siberia's northern shores. Ice and weather conditions are crucial in determining when ships can go through [4].

Data from the Cosmos 1500/Okean series can be transmitted either in real time or transferred to memory and then relayed to ground centres in either:

Moscow
Novosibirsk or
Kharbarovsk.

Images can be transmitted to 570 points, of which 70 are on Soviet ground territory itself. Remote autonomous reception apparatuses are linked into the system.

Side-looking Radar System (SLRS)

Cosmos 1500 was the first of the series to carry a side-looking radar system. It takes a single frame at a time

and can identify land masses and ice-formations by day or by night. Visual images are returned by way of an optical low-resolution multichannel scanner of 1.5km resoluton, and a multichannel microwave radiometer operating at 0.8, 1.35 and 8.5cm.

The SLRS is able to measure wave heights. The intensity of radar reflections is proportionate to the spectral density and energy of wave ripples. The spectral characteristics vary according to winds, currents, and weather systems.

The SLRS has a swath measuring 450km by 500km, and a spatial resolution of 1.5 ±0.5km. Operating frequency is 3cm. The system was designed by the Ukrainian Institute for Radiophysics and Electrics.

Data from the Okean series is transmitted on standard radio links in order to facilitate users. SLRS and optical data are read out side by side for purposes of calibration and convenience.

The SLRS system was not ready for the preoperational missions, Cosmos 1076 and 1151. Instead, they carried a Meteor-series type scanner, an infrared radiometer to measure sea temperature, and a radio system to pick up signals from remote buoys for retransmission.

Ice-fields

The Okean series has an important role in locating cyclones, currents, and vortexes. Photographs and radar images from Cosmos 1500 taken of the Gulf of Finland identified rippling west-driven winds that threatened flooding in Leningrad. In August and September 1984 Cosmos 1500 tracked Hurricane Diana off the east coast of the United States. The SLRS was able to make very precise estimates of surface wind velocities of the hurricane while it was still at sea [5].

The most spectacular results associated with Cosmos 1500 relate to its ice work. The SLRS has proved particularly adept at identifying ice-fields and the depths of icebergs and glaciers.

In October 1984, Cosmos 1500 radar images located a way through the ice for ten vessels trapped in the Long Strait between the east Siberian and Chukchi seas. The images were obtained at night through thick cloud cover.

The Rescue of the Mikhail Somov

In 1985 the arctic explorer vessel *Mikhail Somov* became trapped in Antarctica near the *Russkaya* polar station. Temperatures plunged to −30°C and the crew were in danger of their lives. Cosmos 1500 radar images found a way for the icebreaker *Vladivostok* to reach the *Mikhail Somov* and bring it to clear waters.

The SLRS is so sensitive it can identify oil or petrol spills at sea, distinguish old ice from newly-formed ice, determine cracks and crevices, and locate channels under the ice.

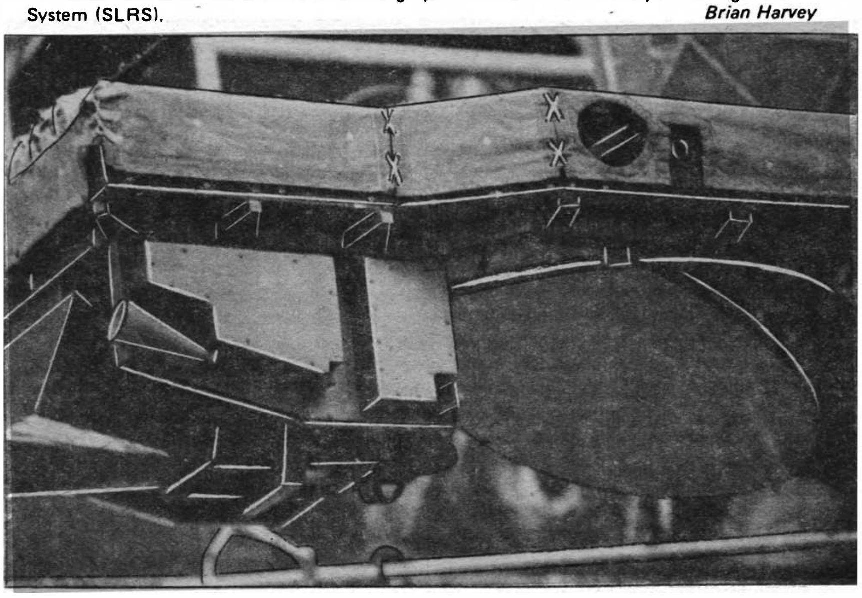
In the course of 1985, Cosmos 1500 compiled an ice-map of Antarctica. New ice cupolas were found on Queen Maud Land, as was an extinct volcano. At the other end of the world, climatically speaking, SLRS images of the Sahara desert found circular structures at 21 N, 11W, that may be the remnants of an ancient fortress now sanded over.

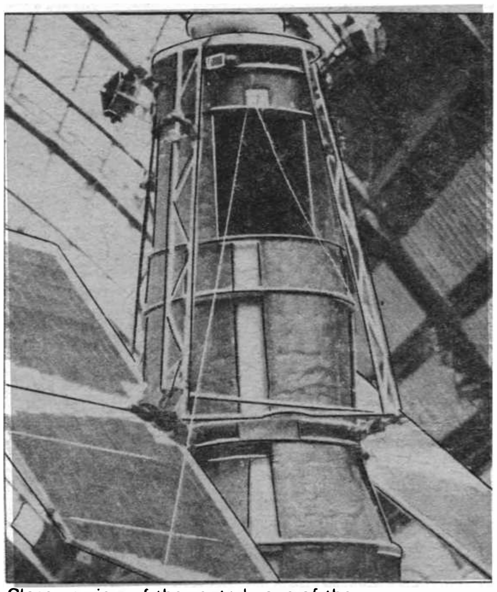
The first operational mission, Cosmos 1500, has been followed by Cosmos 1602 (a year to the day later), Cosmos 1766 (July 1986), Cosmos 1869 (July 1987) and Okean 1 (July 1988). A yearly pattern of launches seems to be established. Cosmos 1869 was only partially successful, the SLRS not deploying correctly.

Recent Developments

The Okean series is part of a growing Soviet earth resources component of its space programme. Several other recent missions have had an oceanographic component.

The main instrument on the Okean oceanographic satellite - the Sideways-Looking Radar System (SLRS). *Brian Harvey*





Close-up view of the central cone of the Cosmos 1500/Okean satellite. Two solar panels are attached to a truss where thev can be rotated to face the Sun. *Brian Harvey*

The enigmatic Cosmos 1870 rode a Proton booster out of Baikonour on 25 July 1987. A Mir-class payload, it was thought to weigh up to 21 tonnes. No physical description has been issued, although the announcement spoke of how the platform would be devoted to hydrology, cartography, and meteorology. Its principal component was, like the Okean series, a radar imaging system. The fact that Cosmos 1870 transmitted on Kvant and Star module frequencies suggested that it was a prototype man-tended free-flying earth resources and ocean studies platform [6].

Cosmos 1940 (April 1988) was the first of a new series of long-promised geosynchronous meteorological satellites. Its purpose was announced as being to study the processes taking place in the Earth's atmosphere and oceans [7]. The Soviet geosynchronous meteorological system is to involve seven satellites in a network called *Prognoz* (forecast). Cosmos 1940 is at 24 W.

The Soviet Union now has a three-element Earth resources satellite system at work : geosynchronous meteorological satellites, the Okean ocean observers, and the mysterious Cosmos 1870 large platform.

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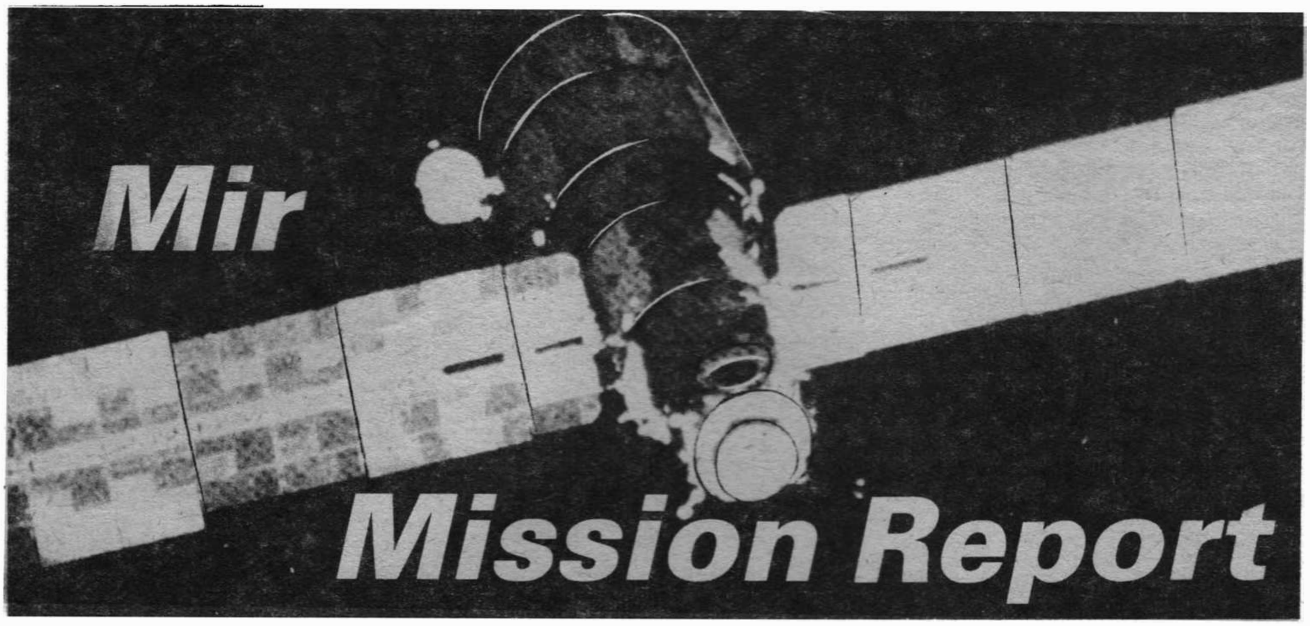


This month the Mir space station celebrates its third anniversary in orbit and two years of continuous occupation by Soviet cosmonauts. During 1988 the space station received visits from three international crews, most recently French cosmonaut Jean Loup Cretien. 1989 will see the addition of a large module to the Mir complex, and the first in-orbit test of the Soviet version of the Manned Manoeuvring Unit. Neville Kidger reviews the latest developments onboard the Mir space station.

TTM Telescope Repaired

On October 6, 1988 TASS revealed that cosmonauts Vladimir Titov and Musa Manarov on the Mir complex were preparing for an EVA which would complete the job of replacing the detector block of the British/Dutch TTM shadow mask X-ray telescope. The detector had failed late in 1987 and the Soviet side had suggested that a repair be effected, according to Dr. Gerald Skinner of the University of Birmingham who helped develop the telescope.

By Neville Kidger

On June 30 the cosmonauts had attempted to effect the replacement of the detector but had encountered difficulties.

According to Birmingham University's Dr. Omar al-Emam, who together with Dr. Skinner had attended a Flight Control Centre at Kaliningrad to help and advise the Soviets during the repair, the two men were heard literally "fumbling" their way along the outside of the Mir/Kvant exterior with the large "platform" containing their tools and the replacement detector block.

The Dutch scientists at Utrecht had refurbished the detector block from a ground version. It was then flown to Mir. Some of the tools were delivered by the Soviet/Bulgarian crew early in June.

Once at the site of the telescope, located in an unpressurised portion of the Kvant module, as a part of the Roentgen X-ray observatory, the cosmonauts discovered that there were more clips to undo than they had been told about. Dr. al-Emam said that the ground version, which the Birmingham team had used to prepare their briefings contained fewer items than the flight model. The Birmingham pair advised the Soviet controller to instruct Titov and Manarov to ignore most of the clips.

However, when the cosmonauts began to cut through some retaining screws they said that the screw heads were covered in resin. After undoing two of the screws the resin caused difficulties with the third. There was some doubt as to the origin of the resin. Shortly after this the station passed out of contact for an hour, Dr. el-Emam said.

When contact was resumed the two cosmonauts had cleaned off the resin with a saw blade and undone the screws. They had also cut some stainless steel clips.

The next task was the insertion of a key into a clamp which secured the detector and then use a lever to open the clamp up. However, after inserting the key partially, struggling to insert it fully, one of the cosmonauts began "screaming and shouting" and said "Oh, the tool's just come off in my hand. It just sheared off!"

Dr. al-Emam thought that a combination of rotational pressure and leverage had caused the tool to shear. The cosmonauts were told to attempt to undo the clamp for about 15 minutes, but if they failed to undo it they were to return to the docking unit from where they had begun the EVA.

The station then drifted out of radio contact again for about an hour. When contact was resumed the two were back at the airlock hatch having failed to remove the clamp. The original timeline for the EVA gave the men nine minutes to obtain samples of the dust-like coating that had overlain the station's windows but that activity was dropped to concentrate on measuring some attachment points for the installation of an anchor point which would be used during the Soviet/French EVA in December. Two French specialists were at the control centre to monitor this activity.

Later, Dr. al-Emam said, the group and the Soviet controllers considered another EVA, possibly for July 5, but decided against it because the outcome could not be guaranteed to be successful. It was decided to postpone the second attempt until a further evaluation had been made.

New EVA Suits

The second TTM repair EVA was apparently substituted for one that was already planned to test out new generation spacesuits.

According to G. I. Severin, chief

MISSION REPORT

spacesuit designer, the new suit is able to be used in an untethered mode. It contains an add-on module which is attached under the suit's backpack, which has its own power source, radio and telemetry equipment. It is "more convenient in the preparation for egress," the Soviets said. It allows for greater palm flexibility and the sleeves and lower soft elastic section can be replaced. The suit's duration was also being extended, making it possible to work in open space for 6–7 hours with 2–3 hours in the airlock.

The chief feature of the suit – the add-on module – allows the wearer to become autonomous of the station's life-support system and permits the wearer to conduct EVAs with a manoeuvring unit.

However, for the TTM EVA, scheduled for October 20, the add-on module would not be used.

Second TTM Repair Attempt

In the week leading up to the EVA the men conducted checks of the new suits as well as continuing their standard routine of experiments and medical examinations. The two cosmonauts were attempting a year-long stay in space and had been joined on August 31 by Dr. Valeri Polyakov.

For the second repair attempt only Dr. Skinner was at the control centre representing the Birmingham team. He was accompanied by a TV team from Central News who were allowed access to both the control centre and, later, Star Town.

Both the Mir multiple docking unit and the Soyuz TM-6 Orbital Module were depressurised for the October 20 EVA due to the amount of equipment that the cosmonauts had to take outside. Dr. Polyakov was sealed inside the Soyuz descent cabin. The spacecraft could be returned to Earth automatically with Polyakov aboard in the event of an accident with the spacewalkers.

Titov and Manarov opened a hatch of the unit at 0659 (all times GMT). The hatch was located at the six o'clock position as seen from Mir's front, according to the FCC display.

Moscow TV began a live transmission at 0715 when Manarov was outside being passed the equipment by Titov. The first TV pictures from the complex showed one of the men waving to the camera from some distance down the station. During the trip to the TTM location, one of the men complained that he had to clamber between handholds that were spaced too far apart.

During the EVA a video relay was broadcast from Star Town to FCC which showed two spacesuited "experimenters" conducting the same operations with the TTM as the two cosmonauts in orbit. Dr. Skinner told this writer that the Soviets did not identify these two men to him.

Dr. Skinner and two Soviet colleagues monitored the EVA from a side room away from the main control room.

The Birmingham team had supplied seven tools for the work and had devised three techniques to break open the clamp. The simplest way was the insertion of a small key into the clamp's lock.

Soviet TV showed photographs of the tools because the only examples of the tools were in space.

The new detector featured handles which made it more convenient for the cosmonauts to work with in their bulky gloves. It also featured a new fastening, a special alignment mark to place it into position and a new clamp design for easier opening. The original detector was not designed for replacement in space.

In addition to the USSR ground station network there were five support ships involved in communications. One ship each was off the coasts of Canada, Brazil and West Africa. The others were in the South Pacific Ocean and the Mediterranean Sea.

At 0850 a report came from orbit that the new key had worked and that the clamp was opened. The detector was removed and the cosmonauts began to install the new one. However, as Dr. Skinner and his colleagues listened on a loudspeaker in the side room, it was becoming obvious that another problem had emerged – the detector did not slide into position first time.

After a few anxious minutes there came a jubilant "hooray" from one of the cosmonauts. It signalled that the detector had been slipped into place and it was then clamped. One of the cosmonauts radioed an "unofficial" report that the detector was in place. The work had been accomplished an hour ahead of schedule.

With their primary task accomplished Titov and Manarov set about a number of others. Once back at the airlock they installed an anchor point to be used during the December EVA and also installed a short-wave aerial. The aerial is to be used for communications between the station, ship and Earth-based radio amateurs. It also provides another line of communications between the men and Earth in the event of a major communications breakdown or in "non-standard" situations.

Finally, the men wiped the space station's windows free of the "dust" film that covered them. The samples were to be returned for analysis. The EVA was ended after 4 hours and 12 minutes.

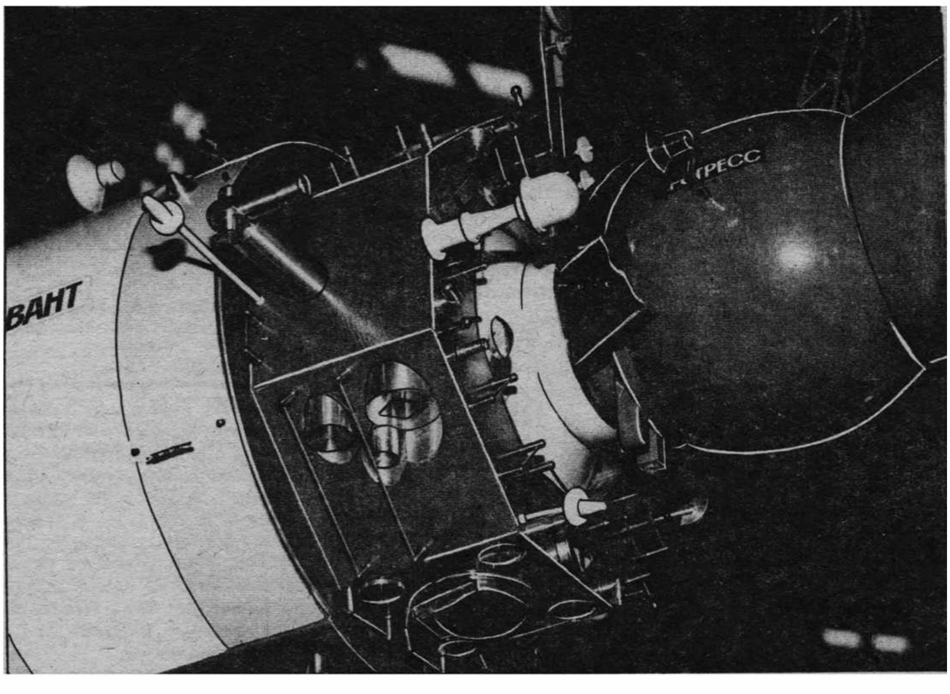
Speaking on TV Dr. Skinner said that the trip had been worthwhile now that the detector had been replaced. It began returning data shortly afterwards.

Continuation of the work

During the following days the cosmonauts and controllers worked with the battery of telescopes and, on October 25, Tass said that over four work-

The telescopes of the Kvant astro-physics module are visible on this Soviet model of the Mir complex. It was in this area that cosmonauts Titov and Manarov had to work during their space walk to repair the TTM telescope. A Progress supply craft is shown docked to Kvant.

P.J. Fulford



ing sessions with Roentgen a detailed analysis of the three brightest X-ray sources in the galactic centre had been conducted by the Institute of Space Research. Spectrograms of these sources showed that the telescope battery's resources had been substantially widened after the replacement of the TTM detector.

On October 27 the Soviets said that Titov and Manarov were using the Chibis suit to simulate gravity and examine their cardiovascular systems. Such sessions are normally increased towards the end of long flights. Work on astrophysics investigation, observations of the flux of particles in near-Earth space and Earth observations occupied the cosmonauts' scientific time. On one occasion, the men sent TV pictures to Earth so that specialists could assess the state of winter crops in farmland areas of southern USSR.

Early in November the men conducted technological work with the mirror-beam furnace and the Pion installation. Samples of aluminium and copper alloys and monocrystals of zinc were processed in the furnace.

Space Endurance Record Broken

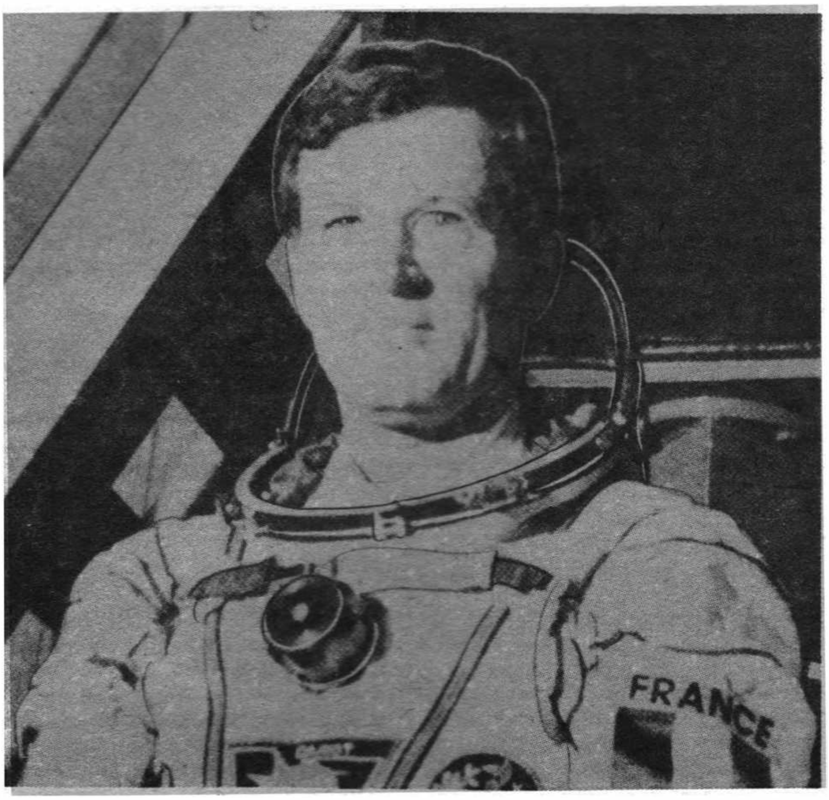
At 2256 on November 11 Titov and Manarov passed the single flight duration record for a space flight set by Yuri Romanenko in 1987. (That record of 326 days 11 hours and 38 minutes would not be officially exceeded until December 14 because the IAF demands a ten per cent increase over the previous record.) Anatoli Grigoriyev, director of the Institute of Medical-Biological Problems of the USSR Ministry of Health (where Dr. Polyakov and Dr. Arzamazov are based) said that no serious deviations had been observed in the health of either Titov or Manarov during their flight beyond the change in weight within the range of 1.5 to 2 kg. There was a forecast that both men would be in good health for their return.

On November 17 the Soviets said that the tanks of Mir's propulsion system were being refuelled by Progress 38. By November 22 the cargo ship had adjusted the station's orbit to one within the parameters of: height 388 × 343 km; period 91.6 minutes; inclination 51.6 degrees. Used equipment was being transferred into the cargo module of Progress 38 in preparation for its undocking.

That event occurred at 1213 on November 23 with the cargo ship being sent to destruction in the atmosphere at an unspecified time after this.

The next day, as preparations on Earth reached a climax for the launch of the Soviet/French visiting crew, the men on Mir concentrated on X-ray studies on the Vela constellation and other medical, technical and geophysical tasks.

Second Soviet/French Space Flight



French cosmonaut Jean-Loup Cretien became France's first man to travel in space twice when he was launched into orbit onboard the Soyuz TM-7 spacecraft. *Novosti*

The background to the second Soviet/French space flight was given in ***Spaceflight***, November 1988, p.418. A description of the joint experiments to be undertaken during the mission was also presented.

On November 10 details about the flight were given to a Moscow news conference.

Cretien said that the mission would "help solve some problems connected with the training of crews for future flights aboard the French spaceship Hermes."

The prime crew consisted of Soviets Col. Aleksandr Volkov and Sergei Krikalev and the French Brigadier-General Jean-Loup Cretien who made the first flight into space for France to Salyut 7 in 1982.

The three men would work with Titov, Manarov and Polyakov until December 21 when Titov, Manarov and Cretien would return to Earth. Volkov, Krikalev and Polyakov would then man the complex until late April 1989 when they would be replaced by another crew.

Volkov, having already made an EVA with Cretien, would conduct two more with Krikalev. These EVAs would see the men install new solar sensors to improve the characteristics of the orientation of the complex. Three cargo spacecraft would deliver scien-

• On November 25, 1988 it was reported that a permanent post office was to open on the complex. The joint Soviet/French crew was to deliver to the complex three cachets – one each to stamp the name of the post office and the date, a special commemorative inscription and a French souvenir emblem. Titov would be designated as "post office chief" and would be given a certificate as such. When he departed, the honour would pass to his successor as Mir commander. Unfortunately for collectors, however, the amount of mail that would be handled by the men on Mir would be "strictly limited" and include letters of the cosmonauts and "special correspondence". The "spatial postmen" would be unable to meet requests for commemorative postmarks but, the Soviet Ministry of Communications said, to console collectors there would be a special stamp issued to commemorate the joint flight about to start. (See p.70)

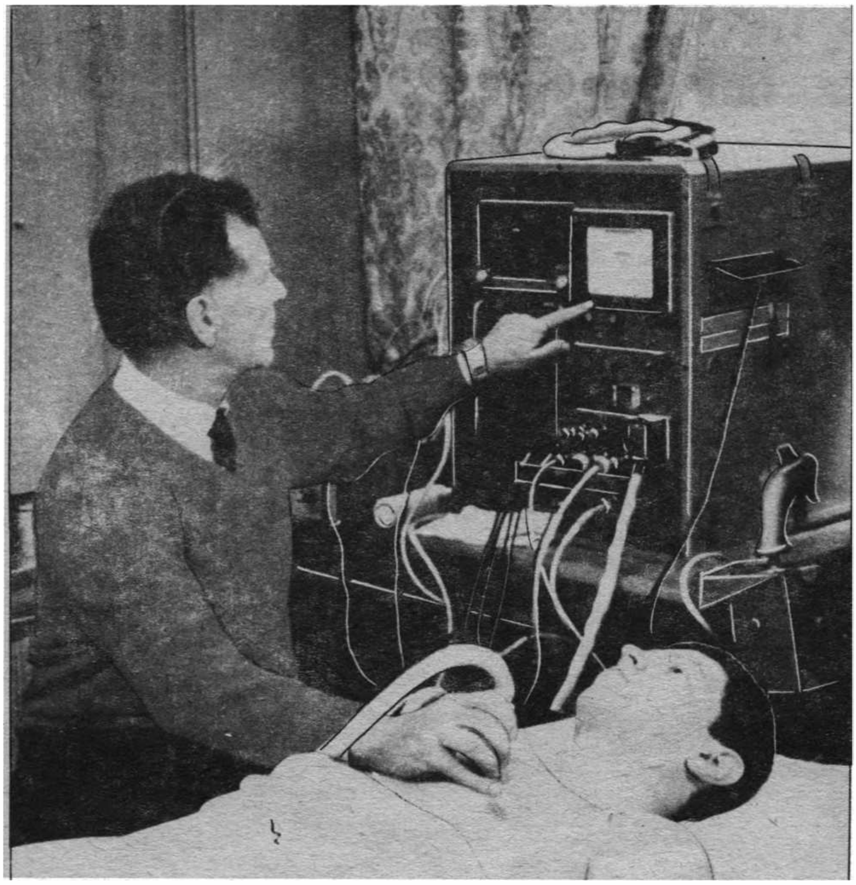
tific equipment and life-support facilities.

Near to the end of their mission a "reequipment" module would be launched and would dock with Mir's front axial docking unit. It would then be transferred to one of the radial ports by means of a small manipulator on the module.

The Salyut-class module, shown to the Central News TV crew and Dr. Gerald Skinner in October, features a compartment of a new configuration for EVAs – with a 1 m diameter hatch for exit to space as opposed to Mir's 0.8m diameter hatches. The crew would activate the module for future use.

It was then planned for the back-up crew of Col. Aleksandr Viktorenko and Aleksandr Serebov to take over the station. (Cretien's reserve, Michel Tognini, may make a flight in two years.) According to one western source, the Soviets have halted year-long flights for the present at the request of the Soviet medical institutes.

Speaking at the press conference Aleksandr Dunayev, the head of the Glavkosmos agency, said that Soviet estimates of the cost of the joint flight were $21 million. He said that ten per cent of this would be compensated for by utilisations of the French-supplied equipment which would remain on Mir and in payment for the stay of Soviet specialists abroad. Although the French did not pay any money for the actual flight, one estimate of the cost to the French side is $30 million.



Jean-Loup Cretien tests the echograph experiment on his back-up, Michel Tognini, during pre-flight training. *CNES*

Presidential Presence

The launch of the Soyuz TM-7, with the Soviet/French crew was delayed from November 21 to November 26 so that French President Francois Mitterand could be present at the Baikonur Cosmodrome. He was to make a two-day visit to the USSR November 25/26.

The launch was also opened to many other correspondents from around the world.

On November 25 these correspondents met with Kerim Kerimov, the chairman of the State Commission which oversees the Soviet manned space programme. He told them that the joint crew was "the first international team in the history of practical preparations for a manned expedition to Mars."

When asked if Mir was to be a base for a manned interplanetary mission by international crews he said it was "irrespective" if the mission took place aboard Mir or a European space station. The task was just too complex for a single state. This stance reflects the oft-cited Soviet desire for international cooperation in certain spheres of space flight.

The correspondents were allowed to walk to the launch pad where the rocket with Soyuz TM-7 atop it was being checked out.

In another press conference the correspondents met the prime crew, which had been confirmed by Kerimov's commission that afternoon. During this Volkov said that one of the Progress ships would bring up to the complex manned manoeuvring units to be used outside the station. They would check them out but that it would fall to Viktorenko and Serebrov to test them outside the station.

In answering a flurry of questions about future Soviet/French missions Vladimir Shatalov, chief of the Star Town Training Centre said that it was possible Tognini would fly and that "it was not ruled out" that a Frenchman would fly in the Buran shuttle craft. "Hermes will not be ready for another ten years and French cosmonauts will have to keep in form somehow," Shatalov said.

A protocol was signed on November 26 which covered the placement of French devices on Soviet stations – possibly the Mir modules – and for a series of missions by French cosmonauts on month-long flights every two years.

Launching Soyuz TM-7

President Mitterand flew into Baikonur by Concorde from Moscow on November 26 accompanied by Soviet Foreign Minister Eduard Shevadnadze. He was taken to the cosmodrome and, in an exchange with the suited cosmonauts, expressed best wishes for the flight. Also at Baikonur was a member of the British pop group "Pink Floyd". One of the cosmonauts had said he liked listening to the group, so the group's record company and the Soviet Embassy in London reached an agreement to fly the cassette and extend the invitation to watch the launch. The group's guitarist is a keen space flight fan, say reports.

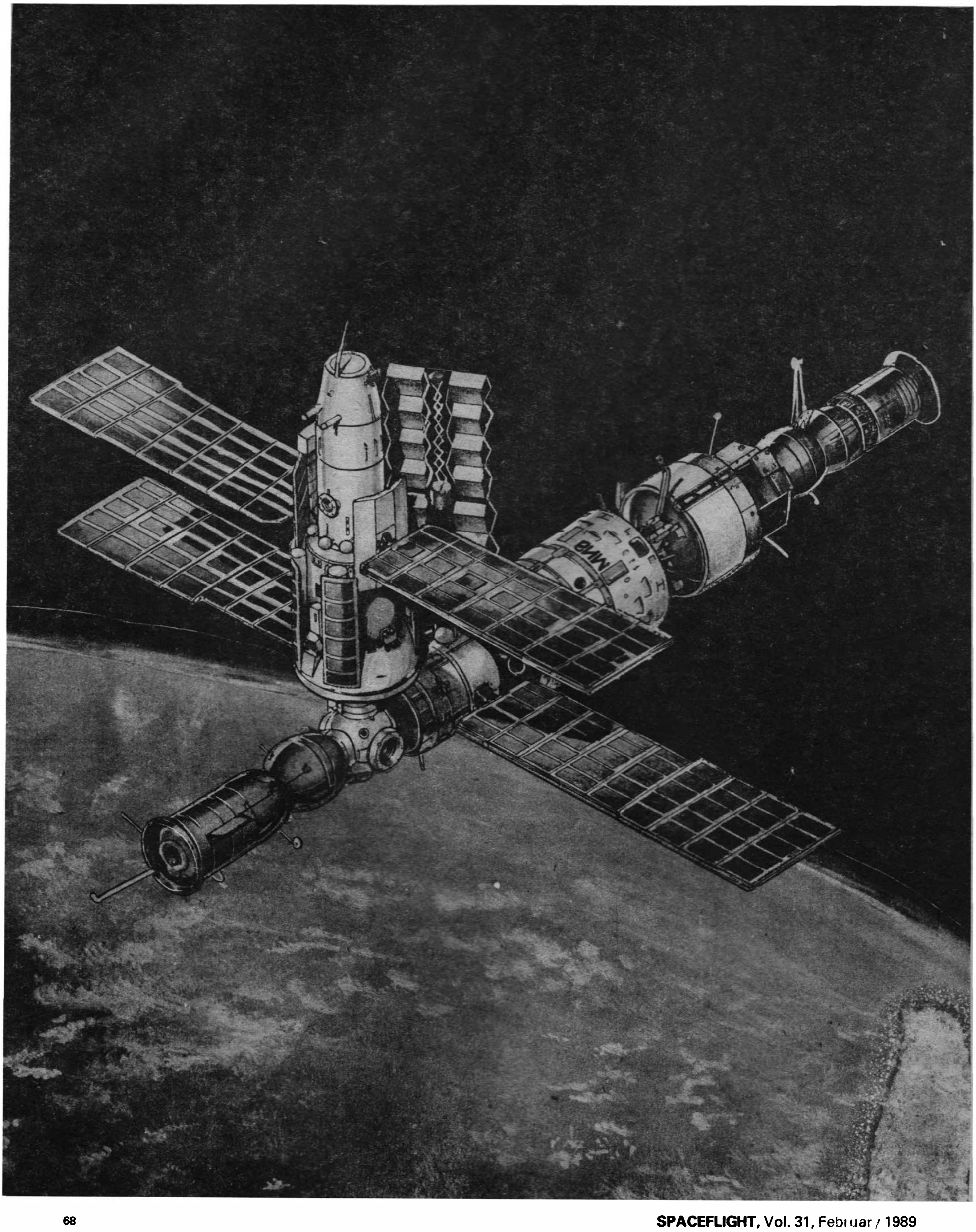
Before the launch President Mitterand was taken, along with some reporters, to see examples of Soviet space technology including a spacesuit with the manned manoeuvring unit and Buran.

Soviet TV and radio covered the preparations for the launch, announced beforehand as being timed for 1549 GMT, live. For the first time, the traditional TV coverage was interrupted for short advertisements for products from watches to banks!

As he lay in the Soyuz TM cabin,

MISSION REPORT

1129



March 1989 US$3.25 £1.25

Spaceflight

The International Magazine of Space and Astronautics

A VISIT TO SPACE CAMP

PEGASUS
WINGED LAUNCHER

MISSION STS-29

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DISTRIBUTION DETAILS

Spaceflight may be received worldwide by mail through membership of the British Interplanetary Society. Details from the above address. Library subscription details are also available on request.

★ ★ ★

Spaceflight is distributed in the UK and overseas through newsagents by Magnum Distribution Ltd., Cloister Court, 22–26 Farringdon Lane, London EC1R 3AU. Tel: 01–253 3135.

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Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published monthly by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L., Ltd., Aylesbury, Buckinghamshire, England.

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Spaceflight

The International Magazine of Space and Astronautics

Vol.31 No. 3 March 1989

Front Cover: (Background) A distant shot of the Tracking and Data Relay Satellite after deployment fromDiscovery in September 1988. A third Tracking and Data Relay Satellite is due to be launched on STS-29 in mid-March.

(Emblem) The STS-29 mission patch - designed by the five crew members to capture and represent the energy and dynamic nature of the US space programme. The stylistic Orbital Maneuvering System burn symbolizes the powerful forward momentum of the shuttle and a continuing determination to explore the frontiers of space. In the border, the seven stars between the STS-29 crew names are a tribute of the crew of Challenger.
NASA

Mid-March Launch for Discovery

This month *Spaceflight* continues its extensive coverage of shuttle missions with a preview of the next flight, STS-29. During the five day flight, Discovery's crew will deploy the third Tracking and Data Relay Satellite (TDRS) and conduct a number of scientific experiments.

STS-29 Crew

Discovery's crew consists almost entirely of the crew for STS 61-H, due for launch in June 1986, but cancelled after the Challenger accident. Discovery is to be commanded by Michael Coats, who previously flew as pilot on the orbiter's maiden flight, in August 1984. Coats was born January 16, 1946, he joined NASA in 1978. Pilot John Blaha will be making his first space flight. Blaha enrolled to be an astronaut in 1980, he was previously an Air Force test pilot. Blaha was born on August 26, 1942.

The three remaining crew members are mission specialists. James Buchli rode the shuttle into orbit on two previous occasions: STS 51-C in January 1985 and STS 61-A in October 1985. Buchli was a test pilot and aeronautical systems engineer before becoming an astronaut in 1978. He was born on June 20, 1945. Robert Springer is making his first trip into space. Born on May 21, 1942, Springer was an operational test pilot before joing NASA in 1980. James Bagian is the only crew member not to be transferred from the cancelled STS 61-H. He was scheduled to fly on STS 61-I in September, 1986, the mission was also cancelled. STS-29 will be his first space flight. Bagian, a medical doctor, was born on February 22, 1952 and joined NASA in 1980.

Launch Preparations

The launch of Discovery has been postponed until mid-March after cracks were found in one of Atlantis' main engines. The cracks were located in the high pressure turbopump of engine No.3. The damage is believed to have been caused when moisture formed in the pump during manufacture. As a precaution, it was decided that pumps manufactured by a new process should be used on STS-29. Rocketdyne, the manufacturers of the engine, worked to prepare the new pumps, which were tested at the Stennis Space Center before being transported to the Cape. All three turbopumps were expected to

STS-29 Mission Specialist James Bagian during emergency egress training at the Johnson Space Center. *NASA*

arrive at the Kennedy Space Center before February 17. The old turbopumps were removed from Discovery on the launch pad.

Discovery was rolled over to the Vehicle Assembly Building (VAB) from the Orbiter Processing Facility (OPF) on January 23. The move was delayed by 24 hours because of torrential rain in the Cape Canaveral area. After arrival, a small nick was discovered in the orbiter's right outboard man landing gear tyre. The tyre was replaced before the vehicle was hoisted vertical for mating.

At 6:00am EST on February 3, Discovery was rolled out to pad 39B. The STS-29 crew rode the Mobile Launch Platform for part of the slow move to the pad.

Countdown Demonstration Test

The five STS-29 crew members took part in a countdown rehearsal at the Kennedy Space Center on February 7. The countdown included a simulated main engine ignition at 11:37am EST. The test gave the astronauts and the ground crews a valuable practice run. A number of malfunctions were introduced during the course of the test, including a complete engine shutdown before lift-off.

The previous day the astronauts had practiced emergency egress from the orbiter and launch pad.

TDRS-D

Discovery's primary payload for STS-29 is the TDRS-D satellite. Two of these satellite are already in orbit, the first launched by Challenger in April 1983, the second was launched in September of last year. A third satellite was lost onboard Challenger in January 1986 1986. (For full details of the TDRS system see ***Spaceflight***, November 1988, p.443).

The TDRS satellite is to be deployed by Discovery during orbit 5, about six hours, 13 minutes into the flight. Backup opportunities for deployment occur during orbits 6 and 7, and also the following day. After the satellite has been deployed, Commander Coats will distance Discovery from the satellite and its IUS booster. To protect the orbiter windows from the IUS ignition Discovery will be turned so its belly faces the satellite. The first stage ignition will occur an hour after deployment, the second stage will fire 12 hours, 26 minutes into the flight.

TDRS-D is to take over the work of TDRS-1, which is now six years old.

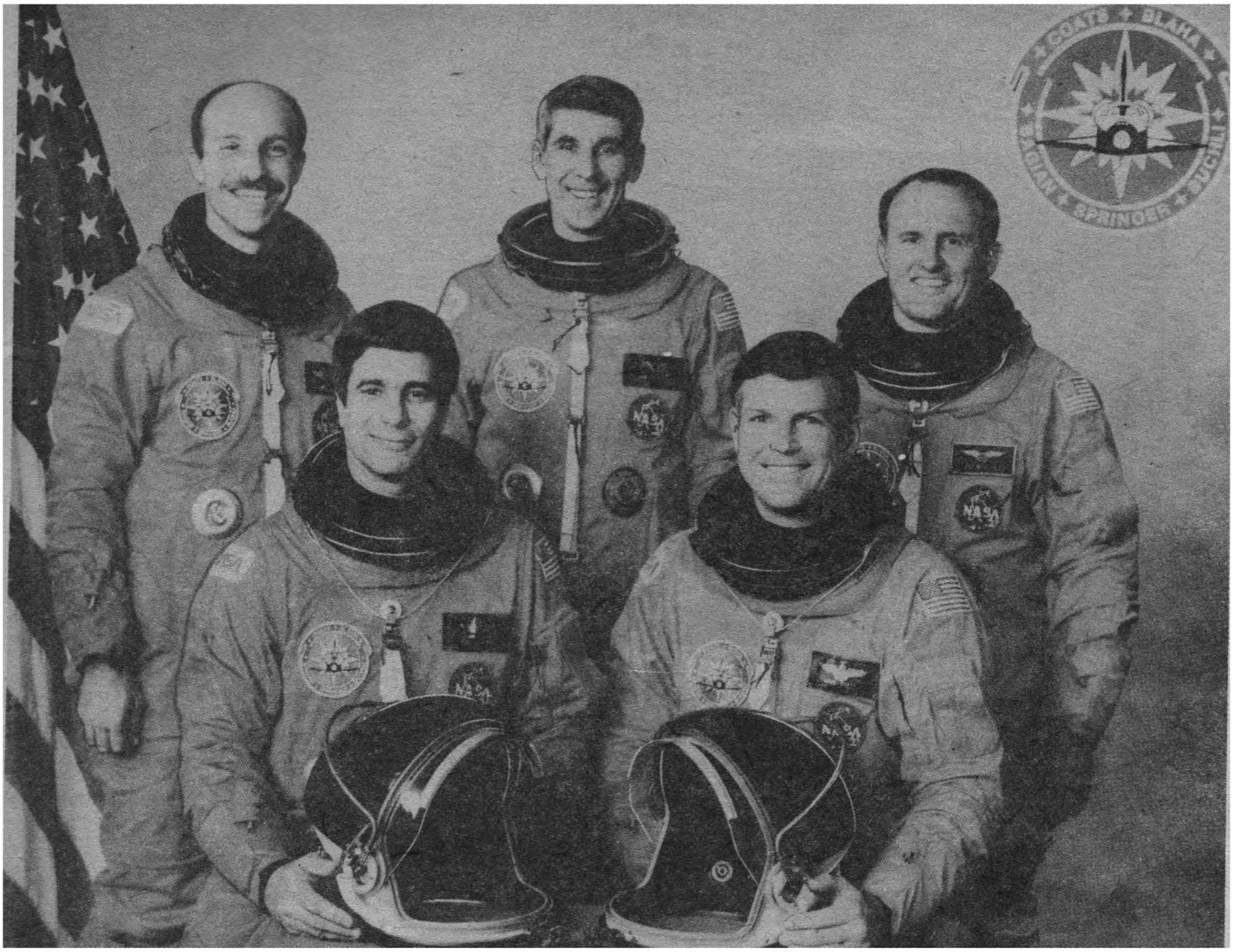
SHARE

The Space Station Heat Pipe Advanced Radiator Element (SHARE) is being developed to cool the space station Freedom, the first full scale test of the system will take place on STS-29. The 15.5 metre long radiator occupies a sill on the starboard side of the payload bay (the sill was originally intended to carry a second remote manipulator arm, but to date shuttle flights have carried just one arm, mounted to the port side).

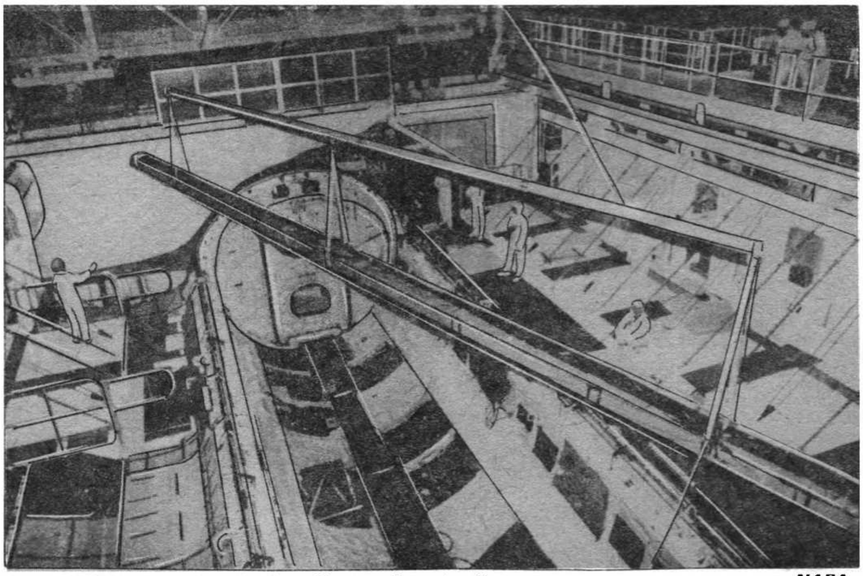
During the orbital tests, three electrical heaters will warm the evaporator end of SHARE. In the evaporator, a fine wire-mesh wick that works on the

(Top) Discovery will be manned by these five astronauts. (Front row) Michael Coats (right) and John Blaha, (left to right back row) James Bagian, Robert Springer and James Buchli.

(Bottom) A little known part of shuttle training - fire fighting. The STS-29 crew are seen here extinguishing a blaze.


COATS
BLAHA
SPRINGER

STS-29 PREVIEW



The SHARE radiator is loaded into Discovery's payload bay. *NASA*

same principle as the wick of an oil lamp will pull liquid ammonia from the smaller pipe into the larger pipe, where it is vapourised by the heat. The vapour will carry the heat the length of the radiator through the large vapour pipe. The radiator element dissipates the heat into space, leaving cooled condensed ammonia. Small circumferential grooves on the wall of the larger pipe allow condensed ammonia to drop back through the narrow slot into the smaller pipe, which recirculates the liquid ammonia back to the evaporator.

An early heat pipe experiment flew aboard STS-8 in August 1983. Although it was small in scale it demonstrated the concept's potential. The SHARE experiment was scheduled to fly in 1986 but has been delayed by the halt in shuttle flights.

During STS-29, crew members will switch on the heaters using controls in the aft flight deck. The experiment's two 500-watt heaters and one 1,000-watt heater are controlled individually and will be switched on in turn, applying heat that will increase steadily in 500-watt increments up to a maximum of 2,000-watts.

The experiment will be activated for two complete orbits in each of the different attitudes, the first with the payload bay towards the Earth and the second with the Orbiter's tail towards the Sun.

For space station Freedom, 50 to 100 radiator panels such as the SHARE would make up two arrays along the station's truss structure. Each radiator will operate independently, thus preventing the failure of a single panel from disabling an entire array.

If the SHARE tests are successfully conducted, the next step will be to evaluate methods for the assenble of the panels in orbit.

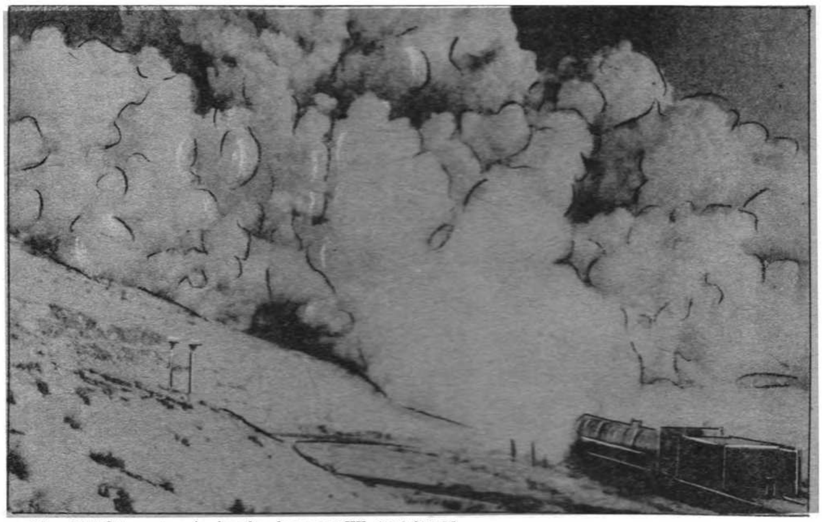
Final Shuttle Booster Test

The final test firing of a full-scale space shuttle Solid Rocket Booster (SRB) was successfully conducted on January 20. The firing took place at the T-97 test stand at Morton Thiokol's facility 25 miles west of Brigham City, Utah.

The test marks the completion of the three-year SRB redesign programme. The booster's field joints, which connect the motor segments, each had the capture feature tang-and-clevis design, with three Viton O-rings and an adhesively bonded J-shaped deflection relief slot, which reduces stresses and also increases the sealing action of the bonded surfaces.

The T-97 test stand features a hanger which can be moved to enclose the SRB. Inside the temperature of the booster can be accurately controlled. For a period of 30 days prior to the test firing the air around the booster was chilled to -6 degrees C. When the hanger was withdrawn, before the firing, the average bulk propellant temperature was 4 degrees C. This is several degrees cooler than any expected motor temperature at launch.

Joint heaters mounted around the motor case at each field joint, are thermostatically controlled to maintain a minimum joint temperature of 24 degrees C. In addition, the igniter joint heaters maintain a minimum temperature of 19 degrees C and the aft skirt was conditioned with heated air to assure a



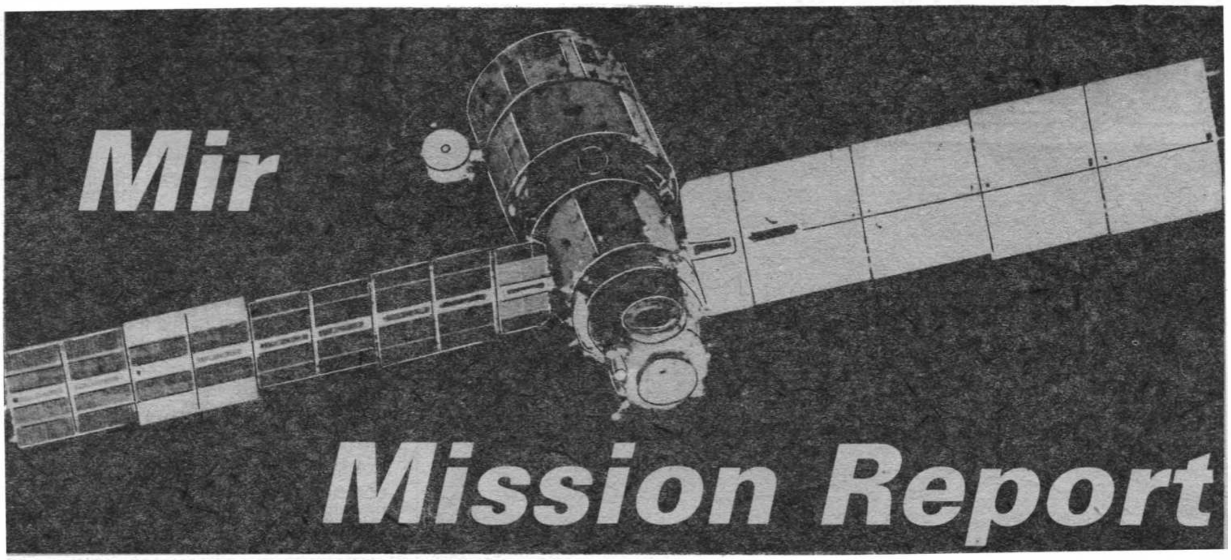
The QM-8 booster during its January 20, test firing.

minimum case-to-nozzle temperature of 24 degrees C.

Unlike some previous test firings, this booster did not contain intentional manufacturing or assembly defects. The motor was equipped with a flight design External Tank (ET) attachment ring. Three hydraulically actuated struts, which simulate the motor's connection to the ET, were attached to the ring. During the motor firing, a programmed series of dynamic loads were applied through the ET attach struts to simulate ignition, lift-off and flight loads.

The QM-8 motor was fitted with more than 600 instruments to measure acceleration, pressure, deflection, thrust, strain, temperature, electrical properties and other conditions.

Although the initial reports say the test was a complete success, it will be some time before this can be verified.



Neville Kidger continues his Mir Mission Report with full details of the joint Soviet/French mission. His report includes the space walk to erect the ERA stucture, and the return to Earth of cosmonauts Vladimir Titov and Musa Manarov, who spent a record breaking year in orbit.

By Neville Kidger

Orbital Experiments Begin

Medical and biological experiments were prominent amongst the first day's work on the complex, November 29. With the Echograph ultrasound instrument Cretien monitored his cardiac activity and the flow of blood through the vessels of his inner organs. The unit is an improved version of the one used by Cretien on Salyut 7 in 1982 and Patrick Baudry on the Shuttle 51-G flight in 1985. Images of the heart are displayed on a small screen during the tests and these are videotaped for later study.

Combined with the Echography tests, biochemical experiments under the codename Medilab used collected plasma and urine samples to study hormonal changes experienced by the cosmonauts during the flight. The plasma would be studied from blood samples collected by means of a Czechoslovak-made instrument. The blood was then to be placed into a centrifuge to separate out the plasma which would then be put into a freezer. Two sets of samples were to be provided - Cretien and a Soviet cosmonaut - so that laboratories in the USSR, France and Czechoslovakia could analyse the plasma and urine together with samples collected before and after the flight.

Michel Tognini, Cretien's reserve later told reporters that there had been problems with the collection of the samples.

Officials admitted that the six men in Mir were working in a crowded environment. A TV shot of Cretien wired up to another experiment showed a maze of cables and wires. The operation of the experiments was also reportedly straining Mir's power supply.

Another novel experiment conducted during the first working day also involved the Echograph unit. By attaching an optical tunnel to the video screen of the unit and linking up a mini-joystick the unit could be used for coordination tests of the subject under the Vinimal codename. The Echograph/Vinimal combination had a total weight of 165kg.

At least six sessions of work involving four scientific objectives were planned for the flight with the first session being on November 29.

The Circe and Ercos units, designed to register radiation levels in the complex and their effect on electronic components, were placed on the walls of the station.

The astronomers on Earth also used the complex to conduct seven observation sessions with the Roentgen observatory on Kvant. They studied the Supernova in the Large Magellanic Cloud as part of the long-term astronomy programme.

The Soviets said that recent observations of the supernova had revealed that the output of hard X-rays had decreased noticably compared to the output at the start of 1988. They linked the decline to the decay of radioactive cobalt.

On November 30 Cretien conducted more Echography tests. He donned the Chibis pneumatic suit during this session to simulate the pull of Earth's gravity.

During this day the first use was to be made of the Physalie experiment which used a number of devices to determine the body's sensory-motor physiology in weightlessness. The equipment used registered numerous physiological signals which included the bioelectrical activity of the heart, muscles, eyeballs and limb movements simultaneously. The subject was also videotaped in stereo.

Before the flight, Cretien had reportedly complained about the complexity of the experiment with a total mass of 75 kg In space he reported that the equipment took up to 2.5 hours to set up. Describing his problems he noted that the complex experiment made the men feel like laboratory animals and that if the windows on Mir opened, then Physalie would be thrown out of them!

The equipment was to be used over eight days of the joint flight with six major scientific objectives being studied.

Okeans Prepare for Return

On December 2 the Soviets said that Titov and Manarov were undergoing special training to adapt their cardiovascular systems and muscles to loads they would encounter on Earth. The regime had become "particularly rigorous" in the final month before the reentry.

The men continued to wear their Penguin load suits almost the whole of their waking hours. The Chibis suit was used often to condition their cardio-vascular systems and water-salt additives help the men to retain liquid and thus increase the amount of blood in their circulatory systems.

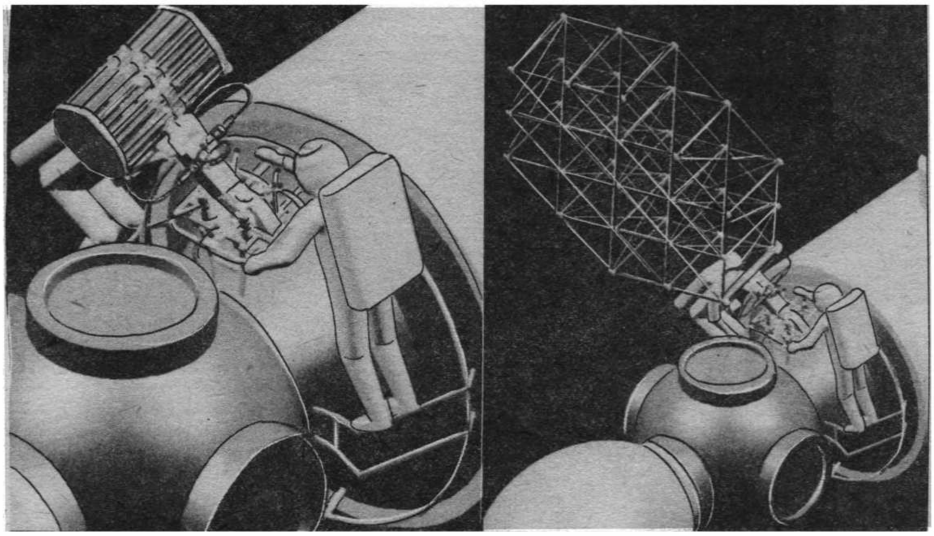
Dr Anatoli Grigoryev said that the men had experienced slight changes in their weight and shin sizes. But these did not exceed those encountered by Yuri Romanenko during his 326-day flight in 1987. He said it was necessary for the two to keep up their exercise programme just as effectively now as they had done for the previous portions of the flight.

On December 4, breaking off from their work, the men held a press conference. Cretien told journalists that he felt better than he had during his first flight in 1982. "Whereas during the previous space mission I was afflicted by space motion sickness, though in a slight form, now I did not feel any sickly sensation," he said.

In TV coverage of the flight the Soviets showed that FCC had been adorned with advertising placards along the base of the display screens. Other reports said that the French had turned down suggestions that Cretien should carry advertising on his space suit. French officials were against that in case the cosmonaut resembled a racing car driver! There were also suggestions that adverts should be placed on the walls of the Mir station.

On December 8 a group of over 50 diplomats from 47 countries visited the FCC to view its facilities. They were given a tour by Aleksandr Dunayev the head of Glavkosmos, and Vladimir Lobachev, the centre's director.

The head of the delegation, the Senegalese ambassador, spoke briefly to the joint crew. After addressing them as "ladies and gentlemen" he wished them every success. The crew thanked the



Computer simulations of the ERA structure in the stowed position (left) and after deployment (right). *CNES*

diplomats for their interest and apologised for having to cut the discussions off after a short reply - the cosmonauts were preparing for the EVA of Volkov and Cretien the next day.

EVA for ERA

When Soyuz TM-7 was launched, the EVA to place the ERA structure on the outside of Mir was scheduled to take place between 0850 - 1350 GMT on December 12. During the first days of the flight the Soviet and French specialists changed their minds and set the date of December 9 (the original date when the launch had been set for November 21). This was to allow another EVA on December 12 if there was a problem with the first attempt to attach and deploy the ERA structure or problems in jettisonning the structure after it had been deployed. Conditions for a second EVA after December 12 were unfavourable, reports said.

After having checked out their EVA suits, early on December 9 cosmonauts Volkov and Cretien entered the Mir front docking unit and sealed themselves inside. The compartment was depressurised and, at 0957 GMT, opened one of the docking unit hatches. The complex was over Japan at the time.

Cretien was the first outside, leaning out to install handrails. Once fully outside at 1016 Cretien attached the Enchantillons experiment to Mir's exterior. This was a 15.5 kg container with several sets of samples inside. There were five different technological experiments being performed:

- Comes, studying the behaviour of materials in space amongst them paints, reflectors, adhesives, filament reinforced composites and optical materials.
- Mapol, studying the behaviour of polymeric materials under exposure to space conditions for evaluation of their feasibility of space applications in inflatable modular structures which can be made rigid.
- DIC and DMC, studying the nature and distribution of dust in space with one active and one passive collector. The active detector measures particle flows.
- MCAL, studying the evolution of solar absorptivity and emissivity over time of white paints to refine mathematical models.

Cretien attached the container to the handrails by means of hooks and springs and connected up a container of electrical leads to the Mir supply. The lids of the containers were then opened to expose the samples. Some difficulties were experienced during this activity.

The experiment is to be retrieved after about six months exposure to open space.

Volkov left Mir's hatch at 1033.

The cosmonauts then moved onto the main purpose of the EVA - the erection of the ERA structure.

The total weight of the experiment amounted to almost 240 kg and comprised four parts - a control panel in Mir, a mounting platform for the structure, the deployable structure itself and a filming block. (It was the largest part of the whole "Aragatz" science equipment which totalled 580 kg.)

The mounting platform was set up on the conical part of the station between the docking module and the work compartment and was attached to handrails. The cosmonauts experienced a problem connecting the cable from the platform to the control panel inside Mir. This further slowed the pace of the EVA, which had been expected to last for 4 hours 20 minutes.

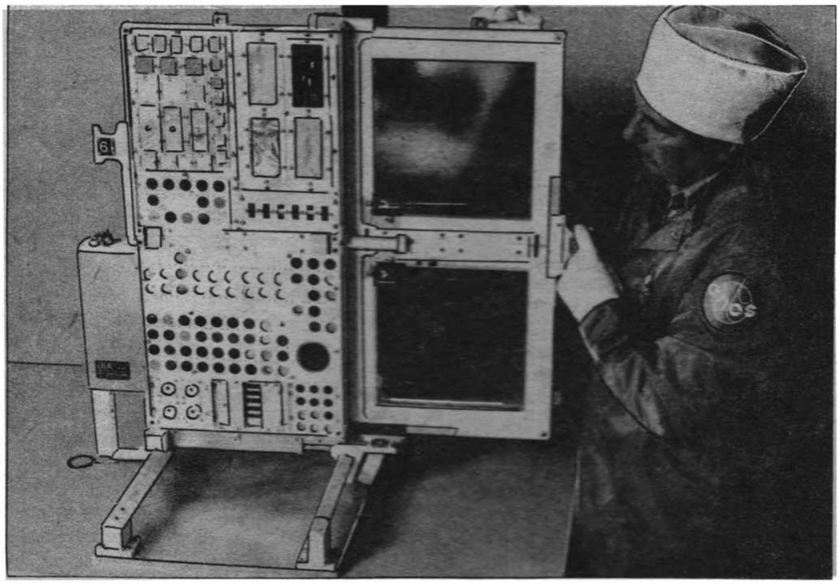
The deployable structure, in its container, was attached to the platform's deployable support arm. Plans called for the arm to be at an angle of 45 degrees with the capability of being raised to 90 degrees if the deployable structure had to be manually jettisoned.

The structure was attached by means of a translation and rotation movement along the axis of the system by the cosmonauts. The operation was videotaped by a camera nearby.

The final operation for the EVA was the actual deployment of the ERA. It consisted of 24 identical prismatic cells made from carbon fibre. Each of the cells had three parallel bars and 12 folding articulated bars with a diameter of 30mm and a thickness of 0.4mm.

When deployed, the structure was 1 metre high with a diameter of 4 metres. The deployment from the bundled configuration was expected to take just 4 seconds and would be videotaped. The structure carried accelerometers,

The Echantillons sample bearing rack, fixed to the exterior of the station during the spacewalk. It will be retrieved after six months exposed to space. *CNES*



temperature sensors and electrical cables to measure loads on it during and after deployment.

However, when Krikalev, from Mir's control panel, commanded the deployment the ERA remained tightly bundled. The cosmonauts applied vibration to the structure, to no avail.

With frustration setting in (one report said much swearing was heard), the Soviet and French engineers met to decide a course of action. Mir passed out of contact with the ground. It was decided that the structure would be cast off undeployed if it failed on the next attempt.

But when communications were restored, via the research ship Akademik Sergei Korolev, the cosmonauts reported that the ERA had deployed. It later emerged that Aleksandr Volkov had kicked the structure several times, against the orders of ground control. The French said the kick which freed ERA was worth FF50 million.

With the experiment accomplished, the structure was cast off. The men brought equipment back into Mir and closed the hatch after a 5 hour 57 minute long EVA, a new Soviet record.

Viktor Blagov, deputy flight controller, said that work was underway to find out why the structure did not deploy.

Later, Phillipe Coillard, director of France's Hermes programme, paid tribute to Volkov's "Courage and resourcefulness" during the EVA. The experience, and the flight of Cretien in general, was helping in the preparation of the Hermes project, the first flight of which is now scheduled for about 1997-1998.

Final Days in Orbit

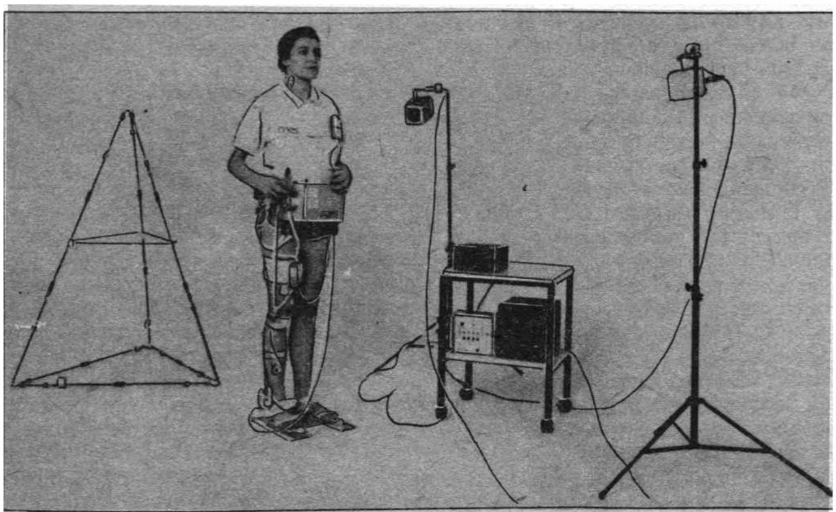
During the next few days Volkov and Cretien finished the final tasks linked to the EVA. Cretien took part in more medical experiments and the complex was oriented in space so that the Kvant module's X-ray telescopes could see the supernova.

Cretien performed two experiments with a model of a frictionless articulated solar panel arm which was being tested for use on future satellites. The experiment, called Amadeus, called for two sessions of unfolding the 28 kg model of the solar arm and for videotaping the results.

On December 14 the crews were involved in more experiments with the Physalie, Vinimal and Medilab equipment. Volkov and Cretien were thoroughly examined with the Mir's multi-functional Gamma medical installation. Titov and Manarov, their year-long flight drawing to a close, had further work-outs with the Chibis suit.

Later in the day the complex was linked up by TV channels to a studio of the French FR-3 station where a group of children from the "Astronaute" Club of Young Cosmonauts were waiting to ask questions of the cosmonauts.

Cretien told the children that after his EVA he was glad to report that he had quickly regained form. He also told them that the crew had taken pictures of the devastated regions of Armenia, where a massive earthquake had claimed many thousands of lives. Cretien said they had learned of the tragedy with "pain and sorrow."



The Physalie experiment. The complex equipment took 2.5 hours to assemble in the weightless environment of Mir. *CNES*

Early on December 15 the cosmonauts broadcast pictures of Dr Valeri Polyakov taking blood samples from Cretien as part of the Minilab experiment. During the day Titov and Manrov officially surpassed the record of Yuri Romanenko for the longest single space flight. He had been in space for 326 days 11 hours and 38 minutes. Titov and Manarov became the offical record holders when they passed 359 days 3 hours and 12 minutes, or 10 per cent more than Romanenko.

In the final few days of the joint flight the cosmonauts took more pictures of the earthquake zone in Armenia and Cretien completed his work with the medical equipment. Physalie and Vinimal were used again.

The resident crew continued their preparations for descent and also monitored how seeds of wheat and lentil were growing in their greenhouses on the walls of the station.

On December 19 the systems of the Soyuz TM-6 spacecraft were checked in preparation for the descent, due on December 21. Titov and Manarov would land with Cretien. The next day the Soviets said that the landing was planned for 0645 GMT on December 21.

During December 20 the cosmonauts stowed the results of the work they had done with photographic and cine films, video and magnetic tapes, spectrograms and biological objects being placed in the descent cabin.

Titov and Manarov conducted the final sessions with the Chibis suit under the watchful eye of Valeri Polyakov.

The Soviets announced that Soyuz TM-7 would be redocked on December 22. Volkov and Krikalev were checking that spacecraft out.

Return to Earth

At 0333 GMT on December 21 Soyuz TM-6 with Titov, Manrov and Certien aboard undocked from Mir's front docking unit. TV pictures showed it moving away from the complex. The landing time was now set at 0648. However, that did not happen. TASS announced a delay in the landing of three hours because of a "Disorder of ... automatic systems."

Viktor Blagov later explained that the fault had arisen due to the faulty interaction between some of the new computer software with the old package of programmes in the Soyuz's on-board computer.

He blamed the problem on a programme for protecting an infra-red sensor against interference. The sensor is responsible for orienting the Soyuz TM before retrofire, Blagov said. The new programme had been inserted after the problems with the landing of Soyuz TM-5 in September, with the Soviet and Afghan cosmonauts aboard.

At that time the TM-5's engines were to be fired as the spacecraft passed the terminator on Earth, but solar rays were falling at an angle of 90 degrees to the sensor's axis and caused the spacecraft to be oriented towards the Sun.

When the angle changed, the sensor reacted by ordering Soyuz to be oriented towards the Earth, but by that time the opportunity for retrofire on that pass had been missed.

The new safeguard programme had been developed to avoid similar situations in the future, Blagov said, but "as it was loaded into the computer and tested on the ground, the possibility of a computing breakdown like the one (which occurred) today was not foreseen.

"The computer signalled that its memory was overloaded, and cut out the landing programme. Then, after consulting ground control, the crew changed to a back-up programme," Blagov continued.

"The on-board computer system

responsible for descent (then) functioned without a hitch. Specialists will now have to adjust the programme taking into account today's problems," he concluded.

An American source notes that the landing date of December 21 was during a period of maximum orbital daylight so that there would be no sunrises or sunsets to confuse the infrared sensor.

The cosmonauts changed the programme in the computer memory at 0808 GMT and exactly an hour later fired the retro engine of the craft to begin the descent as the ship passed over the South Atlantic. Retrofire lasted 4 minutes 30 seconds.

Eight minutes after engine shutdown the Orbital Module was cast off (the module had been retained due to the experience of the Soyuz TM-5 problems) followed at 0933 by the engine section at an altitude of about 140 km.

The descent cabin continued its controlled desent with the use of aerodynamic lift. The cabin became enveloped in plasma and radio contact was lost between 145 to 80 km above Earth. The aerodynamic braking cut the speed to 200m/sec.

At 0944, at an altitude of 10 km the parachute container cover was cast off and the parachute system deployed the 1,000 square metre main chute. Contact was then established between the cabin and the helicopters of the search and rescue service. TV was later shown of the cabin under the parachute desending into a layer of thick cloud.

There were five helicopters carrying journalists but due to the low cloud ceiling (200 metres) the helicopters were told to return to Dzhezkazgan airport. Aleksei Leonov said that a large concentration of vehicles in one area in the conditions created by the low cloud and poor visibility could create a very dangerous situation. The search and rescue teams were coping well with a reserve plan with the landing site having shifted due to the delayed landing.

Soyuz-TM-6 touched down at 0957 GMT some 180 km south east of Dzhezkazgan. Initial reports from the landing site said that Titov had remarked to the rescuers "It has been a long time since I've been here - a whole year." From the controlled environment of Mir the cosmonauts alighted into a chilly minus 14 degrees below zero and a wind speed of six metres per second.

Titov and Manarov had been in space for 365 days 22 hours 39 minutes. Cretien for 24 days 18 hours 8 minutes.

The chief of the search and rescue service reported that the three men were in good health. Cretien was said to have a "wonderful" blood pressure of 120/70.

The cosmonauts were flown by helicopter to Dzhezkazgan and from there to Moscow - a 3.5 hour flight - where they landed at Star Town. The men were to readapt at the training facility rather than at Baikonur, as all previous cosmonauts had done because of an outbreak of hepatitis at the Cosmodrome. TV pictures of the men showed them to be happy and smiling.

The men received a message of congratulation from President Mitterand and were awarded high Soviet and French honours. The French awards were also made to the reserve crew.

Redocking Soyuz TM-7

At 0645 GMT on December 22 Soyuz TM-7, with Volkov, Krikalev and Polyakov inside, undocked from the Kvant port and backed away from the station. The station was commanded to rotate 180 degrees and, under Volkov's manual control, TM-7 was redocked with the front of the station at 0659. It was announced that a Progress ship would be launched on December 25.

Progress 39 was launched at 0312 on December 25 and docked at 0555 two days later with the Kvant port.

On December 25 the cosmonauts and the BBC made British television history when, during a christmas show hosted by Noel Edmonds, a live link-up was made between London and Mir. The three cosmonauts answered questions put to

French cosmonaut, Jean-Loup Cretien, is lifted from the Soyuz T-6 capsule by the recovery team. *Novosti*

them through an interpreter by Edmonds and showed examples of their food, a waste disposal container and the electronic organ left by Cretien.

Volkov also sent greetings to the people of Barnsley, the twin town of his home Gorlovka and showed a mascot - "Sam Barn" - given to him by the staff of the local newspaper in Barnsley.

Finally, Polyakov wished the viewers "A Happy New Year" in English.

For the Soviet space programme 1989 promises to be a very busy year indeed.

Cosmonauts Readapt to Earth

On January 11 TASS reported that Titov and Manarov had almost fully restored their weight, the volume of their muscular tissue and vestibular functions after their extended flight.

During the flight Titov lost almost 3 kg in weight whilst Manarov actually put on weight - almost 2 kg. (Cretien lost 900g during his shorter flight.)

Titov and Manarov developed partial muscular atrophy of the shins, a usual consequence of long-stay flight, the Soviets said. Immediate post-flight examinations showed that their shin volume had decreased by 20 per cent - a little more than Yuri Romanenko. Previously, the Soviet doctors had seen volumes diminish by 25 per cent in cosmonauts who had stayed for shorter periods in space than Romanenko. This was largely due to the loss of intramuscular fluid and not of muscular tissue. This also explains the rapid rehabilitation, Soviet experts said.

Dr Anatoli Grigoryev said that the data on the cosmonauts' bone tissues was still being processed but preliminary results showed that the calcium loss was not as significant as after several previous flights.

Immediately after touchdown, the two men suffered from minor changes in their vestibular function, which passed quickly, and from traditional changes in the water-and-salt metabolism which showed in a 5-6 per cent reduction of the potassium content of their blood.

The men were working to a programme of rehabilitation measures which included jogging, swimming and exercising with a variety of equipment. Grigoryev said that, from the fifth day after their landing, the two men had walked 3 to 4 kilometres and had swum 400 to 500 metres in the pool.

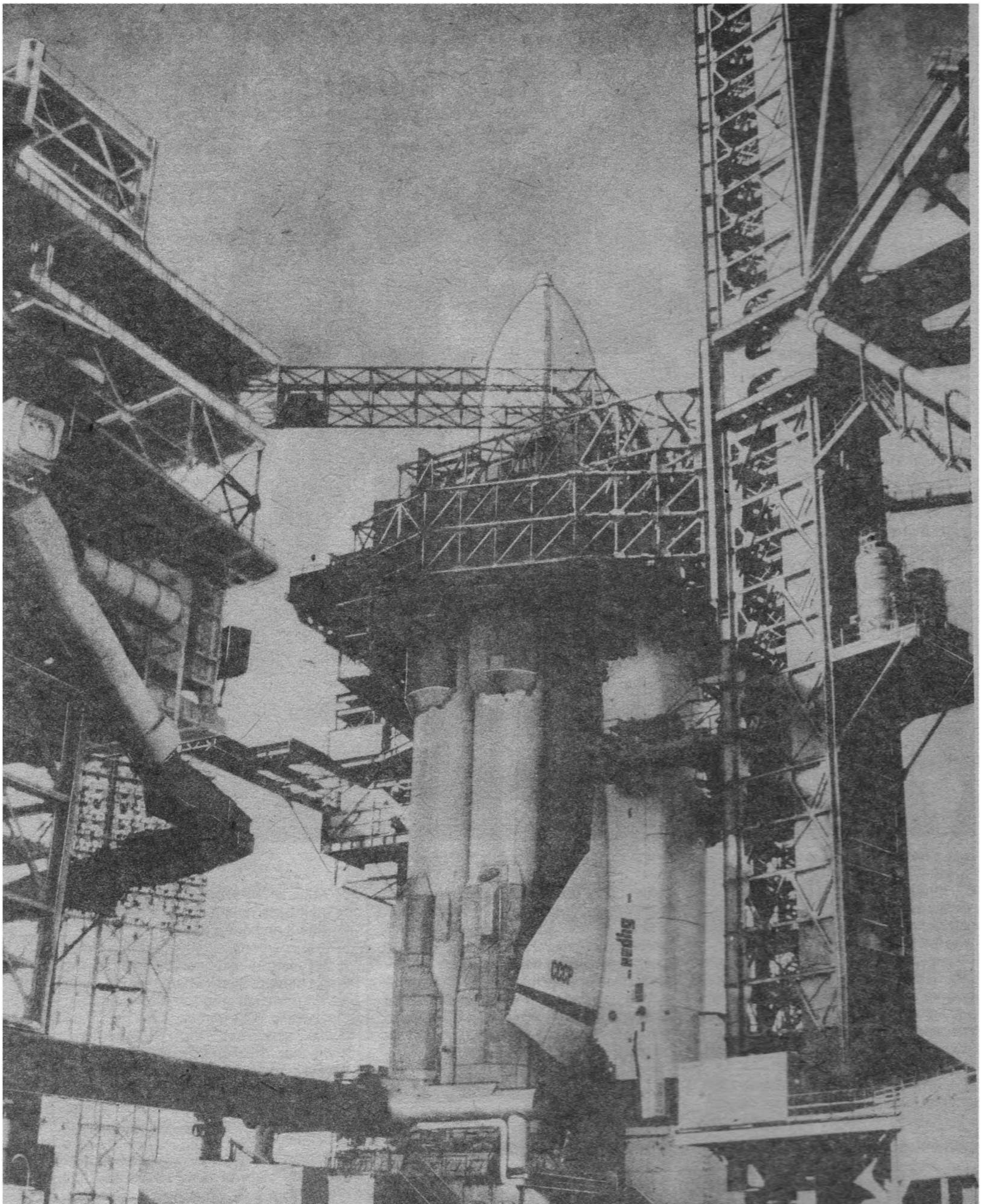
At this time they began intensive training of their back muscles, shins and thighs, for about an hour a day.

The cosmonauts went to the resort of Kislovodsk in mid-January to continue their readaptation where, along with walking, swimming and physical exercises, they would play games, take mountain walks and rest. Yuri Romanenko, Aleksandr Aleksandrov and Aleksandr Laveykin spent time at the resort in January and February 1988. It was anticipated that by the end of February 1989 Titov and Manarov would be fully restored to their pre-flight physical form.

"After this period we will again study in detail the state of bone tissue and the metabolism," Grigoryev said. "Medical control will also be exercised after this for a long time. We must be completely convinced that no unfavourable consequences were left by such a long flight."

Acknowledgements:

The author would like to thank Dr Gerald Skinner of the University of Birmingham, Andrew Salmon, the staff of the Centre National d'Etudes Spatiales and Theo Russell of the Novosti Press Ageny for their help in compiling the past two issues of the Mir Mission Report.



INTERNATIONAL SPACE REPORT

A monthly review of space news and events

Soviet Lunar Mission

The Soviet Union intends to launch a probe to the moon in 1992, according to Professor Yuri Surkov, Head of the Geochemistry and Analytic Chemistry Institute of the USSR Academy of Sciences. The project is titled Luna '92.

Surkov said previous missions to the moon had yielded an enormous amount of scientific information. "Now it is time to get down to the practical utilisation of the moon. This involves first and foremost, telephotography of the lunar surface, including the polar regions, with a resolving power of only a few metres. This is exactly what the Luna '92 and similar projects now on the drawing boards of the United States, Japan and the European Space Agency are intended for." He said.

According to Professor Surkov, the Soviet lunar spacecraft will carry a telecamera, gamma and X-ray spectrometers (to analyse the chemical composition of the lunar soil), an infrared spectrometer (for studying mineral composition), and a magmetometer (for gauging the exact parameters of the magnetic field).

"Apart from the purely explorative purposes, the Luna '92 project will allow us to test once more the equipment for Soviet Mars expeditions." Added Professor Garri Rogovsky of the Babakin Scientific Test Centre. "We intend to make use of the basic design of the Phobos automatic station and its principal systems and components, both for the Luna spacecraft and for subsequent Mars missions."

Phobos Arrives

The Soviet Phobos 2 probe has entered Mars orbit after a 200 day, 470 million km flight. The spacecraft will at first study Mars, then in April it will turn its attention on to the Martian moon Phobos.

Operations to bring Phobos 2 into Mars orbit began on January 23, when the probe's trajectory was corrected for its final approach to the Red Planet. Its braking thrusters fired at 3:55pm Moscow time, on January 29, placing the spacecraft in a 79,750x850km orbit, inclined 1 degree to the Martian equator, with a period of 76.5 hours.

The probe is to carry out a comprehensive survey of the surface, atmosphere, plasma and magnetic envelopes of the planet.

Buran Designers Meet the Press

The designers of the Energia/Buran combination have been speaking to the press about the Soviet Union's reusable space shuttle. The engineers gave an insight into this latest addition to the USSR's space fleet.

The chief designer of the Buran/Energia combination, Yuri Semenov, outlined planned missions for the Soviet shuttle in an interview with the Soviet national daily *Izvestia*.

"Work to develop a new-generation orbital complex to accommodate the heavy-lift booster, Energia, and the orbiter Buran will begin in the next decade."

Buran would "launch costly facilities fitted out with unique scientific instruments, for example large optical telescopes with sophisticated electronic equipment."

Semenov said that helping to construct in orbit a 450-tonne vehicle for Martian manned expedition is among the tasks to be performed by the Energia booster and the Buran reusable orbiter.

He added that the space shuttle could return unique space vehicles to Earth, for example the Salyut 7 space station, which was lifted to a higher orbit in 1986 to delay its reentry.

Semenov pointed out that, unlike the US shuttle, which carries its main engines on the orbiter, Buran only carries orbital manoeuvring engines. Energia delivers Buran to an orbit of about 150–160km, the orbiter then uses its engines to insert itself into the correct orbit.

The Soviet space shuttle, Buran, stands on the launch pad prior to its first flight. This is the first photograph to show the massive 100m main tower in position around Buran. *Novosti*

Semenov said, "to reach an orbit of 250km with a 30-tonne payload, Buran needs eight tonnes of [manoeuvring] fuel. With 14 tonnes of fuel, it can get as high as 450km with 27-tonne payload.

"If an orbit of 800–1,000km has to be reached, Buran can carry an extra 14 tonnes of fuel in supplementary tanks." He added.

Energia 'spin-offs' are being considered. Each of Energia's four strap-on boosters have a thrust of 800 tonnes and is capable of lifting 12 tonnes of payload to orbit. Semenov said the possibility is being studied to use them to launch a new supply spacecraft which will replace the Progress freighters currently in use. This would cut the cost of delivering one kilogramme of payload to orbit by a half.

The various abort modes of the Soviet Shuttle were outlined by the spacecraft designers. Semenov explained: "In the case of a threat to the crew already onboard the ship, there are provisions for their evacuation by slipways into a special bunker guaranteeing their safety. From the moment of the blast-off and in the active period of the lift-off, which means for about two minutes, two members of the crew can be catapulted out with their chairs, just as in ordinary aircraft. The only difference is that on Buran the special powered system will catapult the cosmonauts out to a safer distance of several hundred metres. I repeat that so far only two men can be catapulted out of the ship, but work in that direction is continuing.

"There is also the possibility of the booster rocket going out of control during the lift-off. In that case the orbiter will immediately separate from the booster and would land at one of the airfields along the flight route."

Gleb Lozino-Lozinsky, who was in charge of the development of the Buran orbiter, provided more information on the abort modes.

If one of the rocket's boosters fails, the spacecraft will reach a low orbit and return to Earth after circling once, Lozino-Lorinsky said.

Finally if two boosters fail, Energia would automatically perform a return manoeuvre – a loop with a radius of hundreds of kilometres – and then Buran will detach itself and land on a runway.

Vladimir Barman, chief designer of space launch complexes, said that when the two new launch pads were built at the Baikonur space port, provision was made for every emergency. The facilities at one pad will not be damaged even if there is an explosion at the other.

Besides the landing strip at Baikonur, two more runways are under construction in the vicinity of Simferopol in the Crimea and in the East of the Soviet Union to enable Buran to land from any orbit.

The space shuttle can also use an ordinary airfield if it has no other choice.

"All systems of the orbiter have an in-built redundancy factor," explained Vladimir Lapygin, the chief designer of the Energia/Buran control systems. "In my opinion, this is the main safeguard.

"It is impossible to guarantee absolute safety in such sophisticated systems. This is an axiom. This means all manned flights involved a certain degree of risk. The important task is to minimize that risk as much as possible, and the Buran designers have done their best to accomplish it. This is confirmed by the numerous pre-launch tests, in which the seats were occupied by live people: six cosmonauts headed by the experienced Igor Volk. It is still undecided who will be among the first Soviet pilots to go into orbit onboard Buran. In any case, their actions will be backed up by the automatic systems whose reliability was proved during the unmanned flight."

INTERNATIONAL SPACE REPORT

"US Space Leadership in Danger"—Says Fletcher

Dr James Fletcher, NASA Administrator has warned that the budget of the space agency is "as taut as possible" and "even a nick can mean organic rupture" of the US civil space programme. His words came a week after he unveiled NASA's $13.2 billion budget for the Fiscal Year (FY) 1990.

Speaking to the Explorers' Club in New York, he warned that the US space programme is vulnerable to serious dislocation by even small budget cuts.

He went on to say, the space station project had been subject to so much redesign and modification that "there is simply no room for further trimming, or shaping or cutting. We are either going to build it - and build it right - or not build it at all."

NASA's FY 1990 budget request calls for an increase of $2.4 billion over FY 1989. Much of the increase will be spent on the build-up of the Space Shuttle flight rate, the development of an Advanced Solid Rocket Motor, and the development of Space Station Freedom. The Freedom project will receive $2.05 billion, an increase of $1.15 billion. The space station now accounts for over a third of NASA's Research and Development budget.

Dr James Fletcher

$341.8 million will be spent renovating and constructing facilities at NASA's field centres. Included in this amount is the $26 million required to convert the Orbiter Modification and Refurbishment Facility, at the Kennedy Space Center, into a third Orbiter Processing Facility bay. This will allow three orbiters to be prepared for launch simultaneously.

Fletcher appealed to the Bush Administration, Congress and the public, to support NASA's budget, which has yet to receive approval.

National Aeronautics and Space Administration FY 1990 BUDGET SUMMARY

(Millions of Dollars)

	FY 1989	FY 1990
RESEARCH AND DEVELOPMENT		
Space Station	900 0	2050.2
Space Transportation Capability Development		
Spacelab	88.6	98.9
Upper Stages	138.8	88.6
Engineering & Technical Base	155 4	189 8
Payload Operations & Support Equipment	64.7	81.1
Advanced Programs	52.7	48 7
Tethered Satellite System	26 4	19.9
Orbital Maneuvering Vehicle	73 0	107 0
Advanced Launch System	81.4	5.0
Space Science and Applications		
Physics and Astronomy		
Hubble Space Telescope Development	95.9	67.0
Gamma Ray Observatory Development	41 9	26 7
Advanced X-Ray Astrophysics Facility	16.0	44 0
Global Geospace Science	64.4	112 3
Payload and Instrument Development	81 7	71.4
Shuttle/Spacelab Payload Mission Management and Integration	69.7	86 1
Space Station Integrated Planning and Attached Payloads	8.0	23 0
Explorer Development	82 1	93.2
Mission Operation and Data Analysis	143 2	204 8
Research and Analysis	85.8	112.5
Suborbital Program	45 4	53 5
Life Sciences		
Human Space Flight and Systems Engineering	27 6	42.8
Space Biological Sciences	10 1	27 6
Research and Analysis	40.4	53.8
Planetary Exploration		
Galileo Development	73 4	17 4
Ulysses Development	10 3	14 5
Magellan Development	43.1	
Mars Observer	102.2	100 5
Comet Rendezvous Asteroid Flyby/Cassini		30.0
Mission Operations & Data Analysis	110 7	155 4
Research and Analysis	76.9	79 1
Space Applications		
Earth Sciences		
Upper Atmosphere Research Satellite	94 2	73 9
Ocean Topography Experiment	83 0	72 8
Scatterometer	10 6	13 8
Earth Science Payload Instrument Development	46.4	66.5
Airborne Science and Applications	23 0	19.7
Geodynamics	32.9	38 0
Missions Operations and Data Analysis	17.6	24 8
Research and Analysis	106 0	124 8
Materials Processing	75 6	92 7
Space Communications	92.2	18 6
Information Systems	19.9	34 1
Commercial Programs		
Technology Utilization	16.5	22.7
Commercial Use of Space	28.2	38 3
Aeronautical Research and Technology		
Research and Technology Base	315 6	335.7
Systems Technology Programs	88.6	127.1
Space Research and Technology		
Research and Technology Base	134.1	130 1
Civil Space Technology Initiative	121.8	144 5
Pathfinder Program	40.0	47.3
In-Space Flight Experiments		16.2
Transatmospheric Research and Technology	69.4	127 0
Safety, Reliability and Quality Assurance	22.4	23.3
University Space Science and Technology Academic Program	(22 3)	35.0
Tracking and Data Advanced Systems	18.8	19.9
SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS		
Shuttle Production and Capability Development		
Orbiter Operational Capability	281.8	237.0
Propulsion Systems	582.2	727 3
Launch and Mission Support	264.2	341 0
Space Shuttle Operations		
Flight Operations	685 7	772.6
Flight Hardware	1112.7	1236.5
Launch and Landing Operations	506 8	553 6
Expendable Launch Vehicles	85 5	169 5
Space and Ground Networks, Communications and Data Systems		
Space Network	483 9	582.3
Ground Network	228 1	269 6
Communications and Data Systems	233 3	250 2
TOTALS		
Research and Development	4266 6	5751 6
Space Flight, Control and Data Communications	4464 2	5139.6
Construction of Facilities	[illegible]	341.8
Research and Program Management	[illegible]	2032.2
Inspector General	[illegible]	8.8
TOTAL BUDGET	**[illegible]**	**13274.0**

OBITUARY

Valentin Glushko

We are sorry to record the death of Academician Valentin Glushko (aged 81), an outstanding Soviet scientist and rocket designer. Glushko was involved in the Soviet space programme since its conception. His most recent projects were the Mir space station and the Buran reusable space shuttle.

In the late 1920's Glushko began working on the development of electro-thermal jet engines and liquid propellant rocket motors. In the early 1930s he designed the first Soviet liquid fuel rocket engine.

Glushko was a close colleague of Sergei Korolev, the founder of the Soviet space programme, and in 1974 he took over Korolev's space working group.

During his career he was awarded numerous honours including the Hero of Socialist Labour twice and the Order of Lenin four times. An indication of Glushko's importance was his official obituary, signed by Mikhail Gorbachev, the members of the Politburo, prominent scientists, designers and cosmonauts.

Gorbachev, and other senior government and party figures stood in memory before Glushko's body, lying in state in the hall of the Soviet Army Central House. A funeral service was held at the Novodevichy Cemetry in Moscow.

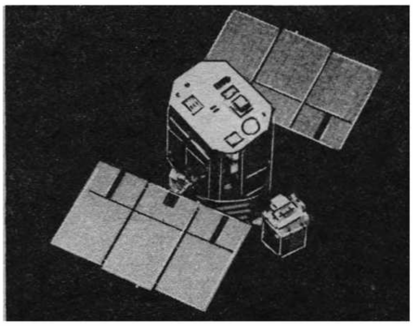
Solar Max Doomed

The Solar Maximum Mission Satellite, better known as 'Solar Max', has been sentenced to an early death by the very forces it was designed to study.

Launched in February 1980, Solar Max has been observing Sun spots, solar flares, the output of the Sun and has contributed towards the study of Supernova 1987A.

NASA scientists had hoped Solar Max would remain in orbit until late 1990 to early 1991. However, an intense burst of solar activity is due to start this year peaking in early 1990 - this will cause the Earth's atmosphere to expand, increasing air drag on the satellite. It is now believed this will cause Solar Max to tumble out of control by the end of the year, and reenter in early 1990.

In December 1980, Solar Max suffered electrical problems which were repaired during shuttle mission STS 41-C in 1984. It was hoped a second rescue mission could boost the satellite into a higher orbit, and carry out further repairs. Unfortunately it proved impossible to include the emergency rescue mission in the tight 1989 shuttle schedule.



Astronaut 'Pinky' Nelson approaches Solar Max, during the 1984 repair mission. *NASA*

More Deltas

The US Air Force has ordered the production of six more McDonnell Douglas Delta II rockets.

By placing the order, the Air Force exercised its last production option on an earlier contract. The original contract agreed upon in January 1987 called for seven Delta II rockets and contained two options for a total of 20 rockets. In February 1988, the Air Force exercised the first option for seven more rockets. Total contract value is approximately $680 million and includes start up costs, special studies and launch services.

The Delta II will be used primarily to boost the Air Force Navstar Global Positioning System (GPS) spacecraft into orbit. The GPS is a navigation satellite system the Air Force will use to provide "pinpoint" accuracy for users anywhere on the globe.

In addition to the Air Force business, McDonnell Douglas has received contracts for two Deltas and five Delta II's, which will be used to launch satellites for commercial and civilian purposes.

SATELLITE DIGEST - 219

Robert D. Christy

Continued from the February 1989 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

[illegible]

Launched: 1020, 22 September 1988 from Plesetsk by A–2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 18 days.
Orbit: 356 × 415 km, 92.30 min, 72.87 deg.

[illegible]

Launched: 1007*, 24 September 1988 from Vandenberg AFB by Atlas-E.
Spacecraft data: Roughly cylindrical body, approx 4 m long and 2 m diameter. Power is provided by a single solar panel at right angles to one end. The mass is 1710 kg.
Mission: Meteorological satellite in sun-synchronous orbit, returning cloud-cover pictures and other weather data.
Orbit: 849 × 865 km, 102.14 min, 98.91 deg.

[illegible]

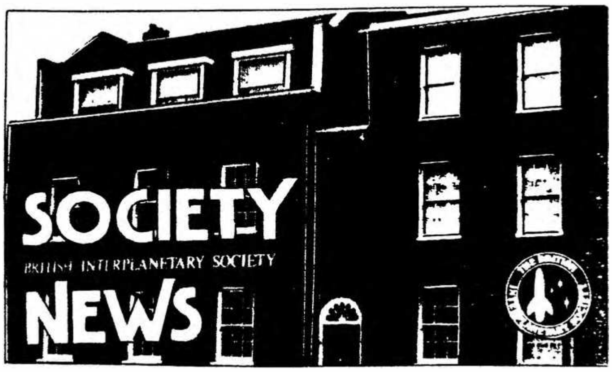
Launched: 0907, 29 September 1988 from Plesetsk by A–2–e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 629 × 38924 km, 701.59 min, 62.86 deg, then raised to 628 × 39714 km, 717.51 min, 62.87 deg to ensure daily repeats of the ground track.

[illegible]

Launched: 1537*, 29 September 1988 from the Kennedy Space Centre.
Spacecraft data: Shuttle Orbiter 'Discovery'.
Mission: Carried crew of Hauck, Hilmers, Lounge, Nelson and Covey. A primary mission objective was to launch the third TDRS-C satellite (TDRS-B was lost aboard 'Challenger' in 1986), 'Discovery' landed at Edwards AFB at 1737, October 3 1988.
Orbit: 299 × 304 km, 90.36 min, 28.42 deg, then raised to 302 × 332 km, 90.68 min for launching TDRS 3.

[illegible]

Launched: 2150*, 29 September 1988 from the payload bay of 'Discovery' by IUS.
Spacecraft data: Hexagonal, box-shaped body, supporting a 'cross' consisting of two dish aerials and two solar panels. The span is about 17 m, and the mass 2225 kg.
Mission: Communications satellite for use in tracking other satellites in low orbit.
Orbit: Geosynchronous above 150 deg west longitude.



Council Convenes for 1989

The first council meeting of 1989 falls due shortly and we take this opportunity to record current Council Membership following new elections at the last Annual General Meeting. Current members are:

Mr. R.A. Buckland	Mr. A.T. Lawton
Mr. G.W. Childs	Dr. L.R. Shepherd
Mr. M.R. Fry	Prof. I.E. Smith
Dr. R. D. Gould	Mr. G.V.E. Thompson
Prof. G.V. Groves	Mr. C.R. Turner
Dr. R. Holdaway	Mr. G.M. Webb

Following our consitutional procedure, the Society's President and two Vice-Presidents, have to be elected annually so this event will be among the first business to be transacted.

£12,000 For HQ Extension

The Society's plans to build an extension over part of its courtyard to enable the Meetings Room and Library services to be extended received massive encouragement from the Will of the late James Hugo Ford, who was not only a Fellow of many years standing but one dedicated to supporting the Society's work.

The late Mr. Ford not only gave freely to assist the Society in the original acquisition of its premises but, by his Will, has enabled the Society to receive a gift of £12,000 from his Estate.

The Council has determined that this sum be placed in the funds being accumulated to enable the Extension Programme to go forward and thus providea fitting tribute to the generosity of Mr. Ford which will be available to benefit all members.

The total accumulated to date in the Building Extension Fund has reached £62,000, which now enables the Council to undertake a realistic study of present-day costs and timescale requirements for the undertaking of this work.

At the outset, the Council divided its plans for the Head–quarters building work into four main Phases with Phase 1 as emergency and essential work, Phase 2 as improvements and renovation to existing structure and Phase 3 as the Building Extension for which we are currently raising funds.

As members and visitors will know, we have now completed Phase 1 which includes a brand new roof on both buildings and a new-looking basement, where the heating, electrical and other services are housed.

Phase 2 has required both funding and planning permission but is well underway and provides the most visible evidence of the renovation taking place. The fact that No. 29 is a Grade II Listed Building means that improvements need to adhere to Local Government regulations, Building Inspection requirements, Fire Officer regulations and the like, so the resolution of these has inevitably imposed limitations on progress.

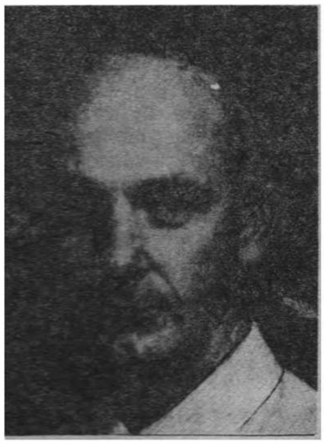
Much of the work now underway or completed also forms essential preliminaries to the Extension by providing better access. At the same time, various outlet pipes are being re-routed to improve working space. All this is additional to the essential repairs which began after the October 1987 storm when we took the opportunity, assisted by a grant from the English Heritage, to rebuild part of the frontage of No. 29 and to re-roof both properties completely.

Many members see the Society premises as more than purely functional offices and want the Society to possess an HQ which gives them both pride and pleasure.

In view of this, the Council has decided to hold a New Members' Evening to give members an opportunity to see the improvements made and to hear about the Society's work. Although the meeting is primarily for new members and a small number of Guests, an invitation is also being extended to longer-standing members, who may not have seen our HQ before and who would like to come along. Full details of the arrangements will be published shortly.

Dr. Richard Holdaway Joins BIS Council

The five Council nominees confirmed in office at the Society's 43rd Annual General Meeting (***Spaceflight***, November 1988, p.435) included one new Council member, Dr. Richard Holdaway, to whom a warm welcome is extended on taking office for the first time.



Dr. R. Holdaway

Dr. Holdaway has been Head of Space Systems Division, Rutherford Appleton Laboratory since 1986, with responsibility for the project management of many space programmes including ISAMS, ZEBRA and SPECTRUM-X. He is also responsible for astrodynamics research and development, including dynamics for orbit determination and prediction, as well as space electronics.

After graduating in Aeronautical and Astronautical Engineering at the University of Southampton in 1970, he worked as a design engineer on the environmental control system for the Harrier VTOL aircraft before returning to the University the following year to carry out research into the use of electric propulsion for spacecraft systems.

After gaining his Ph.D degree in 1974, he joined the Appleton Laboratory (later to become Rutherford Appleton Laboratory) and was Software Design Engineer for the Ariel VI X-ray satellite and Software Manager for both IRAS and the AMPTE satellite programs. In 1984–6 he was UK Ground System Manager for the Roentgen Satellite ROSAT.

Among his other professional activities Dr Holdaway is Chairman of the BNSC Orbits Panel and a member of the Royal Society Space Geodesy Working Group.

Joint BIS-IEE Meeting

'Electric Propulsion' is the subject of a colloquium on March 8, which the Society will be co-sponsoring with the Institution of Electrical Engineers. A previous joint meeting of our two organisations on Electric Propulsion took place in 1973 and the Society welcomes the opportunity to join forces again with the IEE in an important area of Space technology of common interest.

Much progress in developing the techniques of Electric Propulsion has been made over the intervening years and it can be taken as a sign of the times that the forthcoming meeting is to discuss the applications of Electric Propulsion and not the technology itself.

The Society's Representative at the meeting will be Dr. David G. Fearn of Space Department, Royal Aerospace Establishment, Farnborough, who has authored many contributions on ion thruster technology and applications in JBIS.

Dr John Becklake Elected to IAA

We congratulate Dr John Becklake on his recent election to Section IV of the International Academy of Astronautics. Dr Becklake is a Fellow of the Society and is the Chairman of the BIS History Working Group. His present historical research interests are on the history of British Rocketry.

In 1972 he joined the Science Museum in London as the Curator in charge of the Space Technology Collection and now heads the Museum's Department of Engineering while still retaining responsibility for Space Technology. He organized the first major gallery on Space Technology at the Science Museum which opened in 1977 and has since been responsible for the new Exploration of Space Exhibition which tells the story of the development of astronautics from the gunpowder rocket to the space station. A report of the opening of this Exhibition on October 21, 1986 appears in ***Spaceflight***, December 1986, p.436.

Dr John Becklake examines the Congreve Rocket Troop diorama in the Exploration of Space Gallery at the Science Museum in London *Science Museum*

To commemorate the 20th anniversary of the historic Apollo 11 lunar landing, the British Interplanetary Society has organised a series of lectures to celebrate Man's first steps on the Moon, concluding with a dinner at the Society's Headquarters.

Details of the meetings follow:

21 June 7.30-8.30pm
'I WAS THERE'

Reg.Turnill and Frank Miles recall the atmosphere and events of twenty years ago. Reg Turnill was reporting from the US during Apollo 11, while Frank Miles was a member of ITN's 'Space Unit' covering the mission from London.

28 June 7.30-8.30pm
GOING TO THE MOON

Dr R.C. Parkinson considers the BIS contributions to manned lunar concepts. Beginning with its design for a Moonship in 1939, the BIS continued thinking about ways of reaching the Moon throughout the 1950s. This talk illustrates some of the concepts, which culminated in the US Apollo programme.

21 July 8.00pm

APOLLO ANNIVERSARY DINNER

The Society will conclude its Apollo 11 celebrations with a four course meal on the anniversary of Man's first steps on the Moon. (The guests of honour will be announced later.)

All events will be held in the Society's conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Admission for members only. Please apply to the Executive Secretary, enclosing a SAE.

Admission to lectures is free. Apollo Anniversary Dinner tickets are £28.

Obituary

'Doc' Slater being presented with the Silver Medal of the Royal Aero Club by HRH The Prince of Wales in 1979

We much regret to record the death of Dr. Alan Edward Slater, M.A., M.R.C.S., L.R.C.P., a few weeks before his 93rd birthday.

'Doc' was born in 1894, and educated at Abbotsholme School, Cambridge University, and St. Thomas' Hospital. He obtained a Cambridge B.A. degree in Mathematics and Music (obtaining a 1st Class degree in Music), and then took up medicine as a more certain means of livelihood, qualifying as a medical practitioner in 1922 and joining the Fever Hospital Service of the L.G.C. in 1924.

Doc became the first British Glider Pilot to obtain a gliding certificate without previously flying aeroplanes. In 1933 he accepted a spare-time post as editor of *Sailplane and Glider* but this soon grew to such proportions that he had to give up his medical career in 1936 to start a new career in journalism. He returned to medicine during the war, this time with the L.C.C. Mental Hospitals Service.

Dr. Slater joined the Society in 1945 and became editor of the revived BIS Journal in 1946, but was forced to give it up after editing three issues owing to pressure of other work. He served on the BIS Council from 1946 to 1973.

In 1952 he gave the first of many of papers on Space Medicine to IAF Congresses, beginning with the likely physiological problems of weighlessness in space flight. A further paper in 1957 was concerned with the improbability of homo sapiens developing elsewhere in the Universe and, in 1958, he played a leading role in organising, on behalf of the Society, its first international symposium on Space Medicine.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Subject to space being available members may also apply for a ticket for one guest.

March 1 1989, 7.00-8.30 p.m. **Lecture**

SOME INTERESTING SPACE PIONEERS

This lecture by Professor Ian Smith reviews the contribution made by a number of noted space pioneers known to the speaker.

Admission is by ticket only Members should apply in good time enclosing a stamped addressed envelope

8 March 1988, 2.00-5.00 pm **Colloquium**

ELECTRIC PROPULSION COLLOQUIUM

A meeting co-sponsored by the British Interplanetary Society and the Institution of Electrical Engineers The primary aim of the meeting is to discuss the applications of Electric Propulsion, not the technology itself

For more information please write to the Executive Secretary, 27/29 South Lambeth Road, London, SW8 1SZ

5 April 1989 7.00-8.30 p.m. **Lecture**

THE PROSPECTS FOR SPACE TOURISM

This lecture by David Ashford, will propose that Europe should develop a small fully reusable aeroplane-like launcher, as an alternative to Hermes, which could actually cost less to develop It could lead to a space tourism industry starting this century and developing into a large, if not the largest commercial issue of space

Admission is by ticket only Members should apply in good time enclosing a stamped addressed envelope

13 May 1989, 10.30 am **Visit**

UKAEA CULHAM LABORATORY

A tour of the United Kingdom Atomic Energy Authority s Culham Laboratory which is concerned with nuclear fusion and plasma physics research, and is the home of the Joint European Torus (JET) Project The tour will include the Control and Assembly Rooms

Admission is by registration only Members should apply before 15 Apr enclosing a stamped addressed envelope

3 June 1989 10am-4.30pm **Symposium**

SOVIET ASTRONAUTICS

Venue Conference Room British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ

Offers of Papers
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LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

The Pegasus Launch Vehicle

Following the loss of the Space Shuttle Challenger, an intensive effort got underway to build up the United States' expendable booster capability for both Air Force and civil users. These boosters include the Atlas II, Delta II, Titan II, Titan IV and, on the horizon, the heavy lift Advanced Launch Vehicle and Shuttle-C. As part of this, work began on a small booster that would use a completely different profile. This is the Pegasus air-launched booster.

By Curtis Peebles

Air Launched Systems

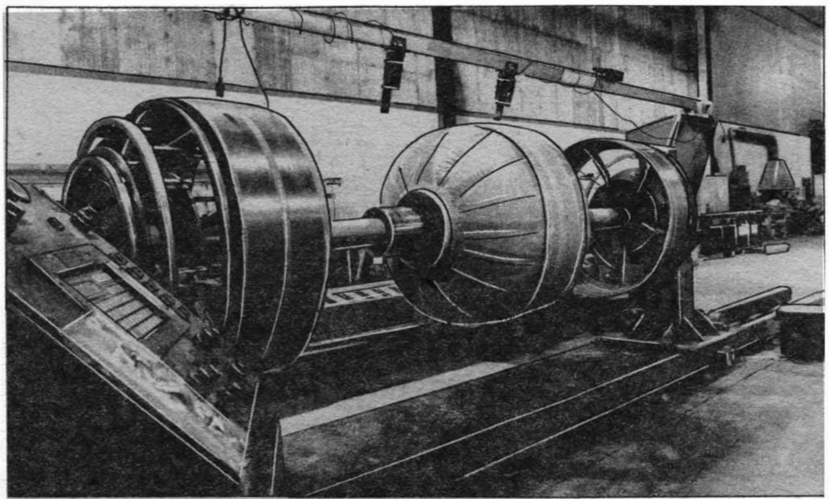
The idea of launching a satellite from a conventional aircraft is not new. In the early 1960s, the U.S. Navy undertook Project Hi Ho. This involved the launching of a small Caleb rocket from a McDonnell F-4 H Phantom. It was to test the feasibility of launching satellites and space probes from aircraft. Two test launches were made at the Pacific Missile Range in April and July 1962. The second rocket reached about 1,600 kilometers. [1]

More ambitious was a study of using the NB–52/X–15/Blue Scout as a partially reusable launcher. The X–15 would be launched in the normal way. As it climbed through 47,550 meters, the X–15 pilot would launch the Blue Scout. The missile was to be carried on the X–15's underside on a rack/fairing forward of the lower fin. The Blue Scout had three solid fuel stages – an ABL X–259 first stage, an AJ–10 second stage (both from the U.S. Air Force Blue Scout Junior) and small NOTS 100A third stage. [2] The project did not go beyond studies and the concept of an air-launched satellite fell out of favour.

This changed in 1986–87 with the start of the Defense Advanced Research Projects Agency (DARPA) "Lightsat" program. Rather than single, very large, expensive and long lived satellites such as the Big Bird and KH–11, the Lightsat envisioned using small, relatively cheap, but more numerous satellites. Work on the Pegasus began in early 1987 when Dr. Antonio L. Elias, chief engineer at Orbital Sciences Corporation (OSC), suggested the company look at a low-cost, air-launched booster. Development work began in April 1987 with the $40–45 million cost split between OSC and Hercules Corporation. In February 1988, DARPA issued a request for an air-launched booster. During the summer of 1988, a contract was finalized between OSC/Hercules and DARPA. This cleared the way for construction of the first Pegasus booster [3,4]

Pegasus

The Pegasus booster is 15 metres long, has a wingspan of 6.7 metres and weighs 18,144 kilograms. This is virtually the same as the North American X–15. It is not a coincidence – the Pegasus is designed to fit the NB–52B used to carry the X–15 two decades ago. X–15 test data was used during the Pegasus' early design as it was found both had similar low-speed release dynamics and separation trajectories.



The Pegasus launch vehicle under construction at Hercules Aerospace's facility in Utah. OSC

The Pegasus has three Hercules solid fuel stages each 1.27 metres in diameter. The wings and fins are of graphite composite and are being built by Burt Rutan's Scaled Composites (which also built the Voyager round the world aircraft). Originally OSC looked at wingless boosters but found that adding a wing gave several advantages. First was that at a 4:1 supersonic lift over drag ratio, the wing's lift exceeded the performance of the rocket alone. A wing also means a flatter trajectory can be flown which lessens stress and control problems. A delta wing was used to fit under the NB–52's wing. The design of Pegasus was done using NASA's Cray 2 and Cray XMP supercomputers rather than in a wind tunnel.

The advantages of an air-launched booster are several – the airplane's velocity adds 1–2% to the rocket's performance. More important the air pressure at launch altitude is 25% that at sea level. This allows a better rocket nozzle design as it does not have to be compromised for operation from sea level up to a near vacuum. The high altitude launch means lower dynamic pressure as well as lower structural and thermal stresses. Taken together this means a 10–15% reduction in the total velocity it would have to achieve for a given payload.

The result is the Pegasus can put a 272 kilogram payload into a 463 kilometre polar orbit or 408 kilograms into a 463 kilometre equatorial orbit. The satellite is fitted into a payload shroud 1.83 metres long with a 1.17 metre diameter. This large volume and payload weight will allow various satellite designs including ones with large optical systems. [5]

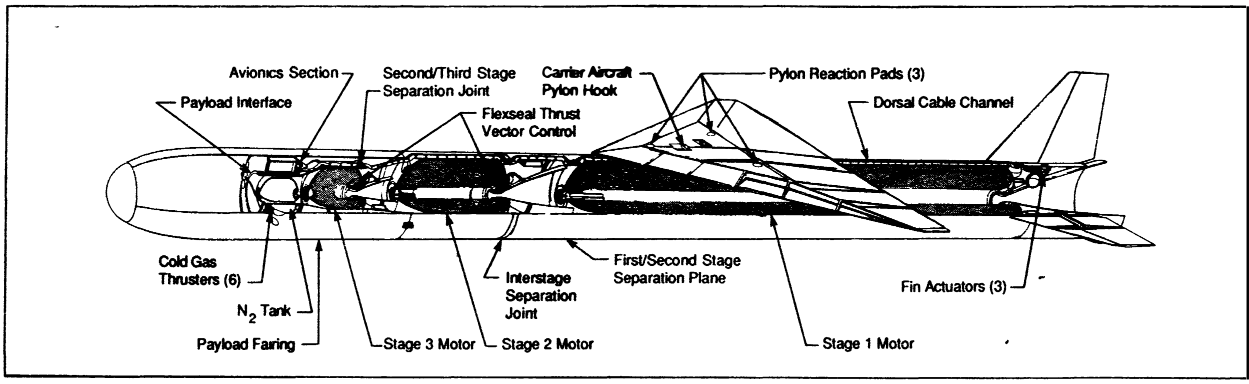
Pegasus Launch Profile

The launch profile of the Pegasus is unlike that of a conventional booster. Its three stages are assembled horizontally on a truck trailer by a 6 man team. Preparation will take about two weeks once the project is fully underway. To protect the booster, assembly is made in an air conditioned building. As additional protection, a tented area on the trailer provides a clean room environment for the satellite until the payload shroud is in place.

The complete Pegasus will be brought out to the NB–52B launch aircraft about two hours before takeoff. Joining the two vehicles will take about an hour. Once linked, the NB–52 will provide 28 volt D.C. electrical power and the Pegasus will be controlled by the aircraft's mission computer. Check out will be through the Pegasus' own telemetry system.

The NB–52 will takeoff from Dryden Flight Research Facility at Edwards

The Pegasus climbs towards orbit. Its NB-52 carrier aircraft is visible below the launcher.



Continued from p.89

AFB. The Aircraft Commander, for the first few launches, is planned to be Col. Gordon Fullerton, ex-Shuttle astronaut and chief B–52 pilot at Dryden. The drop point will be off Vandenberg AFB. The Control Panel Operator had a PC-sized mission computer, a telemetry receiver and a reference inertial measurement unit for updating the Pegasus' guidance system. The operator also downloads mission data into the guidance system and turns on the pilot's drop switch. If the drop has to be halted, the Control Panel Operator carries data for alternate drop points. This adds flexibility. It is the pilot who makes the final drop decision for the Pegasus. [6]

At the drop, the NB–52 is flying at Mach 0.8 and 12,000 metres. The Pegasus free falls for 5 seconds and 100 metres below the NB–52 before the first stage ignites. The Pegasus makes a 2.5 G pull up under the control of the three tail fins. The first stage has a maximum thrust of 59,422 kilograms. As first stage burn out nears, the wings began to char. First stage burn out comes at 81.3 seconds after the drop at an altitude of 63,390 metres and a speed of Mach 8.7. Separation and a 5.8 second coast follows. A cold gas reaction control system stabilizes the booster. The second stage then ignites 87.1 seconds into the flight. At 121 seconds, the payload shroud separates. The second stage burns for 71.4 seconds with a maximum thrust of 14,061 kilograms. Guidance control for the second and third stagesis by a gimballed nozzle. At 158.5 seconds, when the Pegasus is at 167 kilometres and a speed of 5,425 metres per second, the second stage burns out. The Pegasus then coasts for 310.6 seconds. At 469 seconds into the flight, when the third stage reaches an altitude of 459 kilometres, it ignites for a 64.3 second burn to accelerate the payload into orbit. The cold gas jets, used to stabilize the booster during coasts, now spin up the satellite before release. [7,8]

Plans and Prospects

In the summer of 1988, it was planned the first Pegasus launch would be made in July 1989. The payload would be a DARPA built package of several small store and dump communication satellites. The second launch, carrying a military satellite, would be made in October. The third launch would follow in December 1989 with a NASA space science payload. [9] In late 1988, this plan changed. The first launch's payload was now to be a NASA instrument package to measure wing and body data. The goal of the flight is a final test of the launcher before risking a costly payload. If all goes well the second flight will carry the multiple satellites. [10] The first 15 or so Pegasus launches will be made using NASA's NB–52B. In late 1990, OSC hopes to shift to a heavy transport as launch aircraft. Not surprising, given the NB–52 will, by that time, be almost 40 years old and have made over 450 drops (including 199 X–15 flights). Edwards AFB is seen as the only base for the foreseeable future.

OSC and Hercules believe 16–18 launches over 2 to 2.5 years will be needed to reach the break even point. The launch rate is projected to be 10–12 launches per year. They believe a viable launch service can be based on as few as 5–6 per year. A Pegasus launch is estimated to cost $10 million. (The NB–52 cost $30,000 per hour and a launch takes four hours). The small assembly crew, the sealing of electronics, thrusters and other critical systems, so they do not need a clean room, and a lack of back up systems (except for the destruct system) are all intended to keep costs down. The estimate is a Pegasus launch will cost half that of a conventional booster. [11]

Among the prospective satellites for Pegasus are, in addition to the Lightsats, communications satellites, remote sensing, materials processing, geolocation and certification of electronics for space flight. These could be both U.S. and international. Another possibility is acquiring data for the National Aero Space Plane. Pegasus could carry a 680 kilogram data payload. The early Pegasus flights will be instrumented for NASP data. [12]

Once past the initial flights, Pegasus will then have to find a part of the commercial launch services market. OSC believes there is a broad enough market for Pegasus to thrive. If one segment does not develop as anticipated, it will not threaten the whole. Still there are uncertainties – the difficulties of an advanced commercial project, possible technical problems, changes in space policy by the incoming Bush administration or renewed questions about the Lightsat programme (which achieves low costs at the price of reduced capabilities).

Whatever the final outcome, Pegasus is a unique project. It is a booster developed through private funding that uses an unconventional launch profile to achieve low cost and flexibility. Pegasus can also be seen as the historical continuation of such experimental aircraft as the X-1, D-558 II, X-2 and X-15. All used air-launching as the first step to ever higher speeds and altitudes. Pegasus would carry that tradition into orbit.

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Acknowledgement

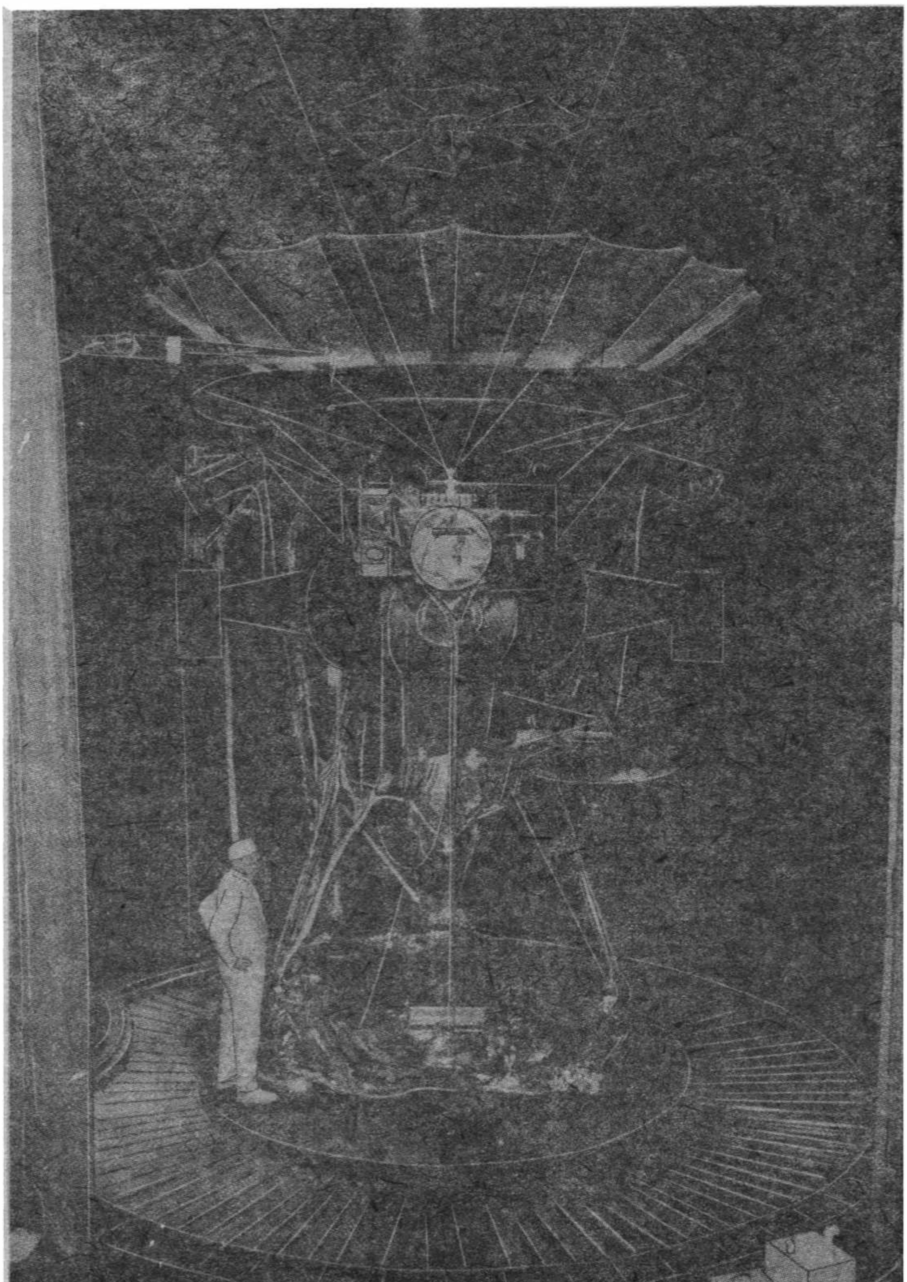
The author would like to give special thanks to Orbital Sciences Corporation.

Galileo at Venus

The launch period for the Galileo mission to Jupiter opens on October 8, 1989, and the spacecraft will arrive at Jupiter on December 7, 1995. However, prior to arrival at Jupiter, six encounters with solar-system bodies are planned: Venus (Feb. 1990), Earth/Moon (Dec. 1990), asteroid Gaspra (Oct. 1991), and Earth/Moon (Dec. 1992). A seventh, with asteroid Ida (Aug. 1993), is also an option if the Gaspra results indicate the required expenditure of propellant is justified. The three planetary encounters are scheduled in order to give Galileo gravity assists which will send it to Jupiter. Prior to the Challenger accident in 1986, the powerful Centaur rocket, serving as an upper stage for the Shuttle, would have enabled the spacecraft to cruise directly to Jupiter in about two years. After cancellation for safety reasons of the combination of Shuttle with Centaur, mission designers at JPL created this tour of the inner solar system, substituting planetary energy to cover the shortfall in chemical energy.

Galileo's flyby of cloud-covered Venus, at an altitude of 15,000 km, provides a scientific bonus which complements the Magellan mission to that planet (April 1989 launch and August 1990 arrival); the Magellan orbiter will primarily map the Venusian surface with a synthetic aperture radar while Galileo's payload is suited for atmospheric studies and investigations of fields and particles phenomena.

The scientific investigations planned for the February 1990 visit of Galileo to Venus have been parcelled into three categories: first time, collaborative and corroborative. The first category is self explanatory. The second, a scientific collaboration, will be undertaken between Galileo and NASA's Pioneer Venus Orbiter, launched in 1978, which is still actively engaged in Venusian research. The



The Galileo spacecraft is subjected to realistic environmental conditions in JPL's space simulator prior to its scheduled October 1989 launch. *NASA/JPL*

third refers to observations which relate to investigations carried out by previous spacecraft at Venus.

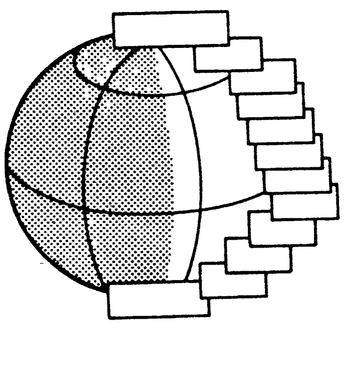
One of the first-time scientific objectives is to map, in the infrared, features and motions in and below the cloud deck on the dark side of Venus. Observations from Earth have revealed areas of surprising brightness variations on the dark side of Venus in the spectral range of 1.5 to 2.5 microns. (A micron is one millionth of a meter and the wavelength of visible light lies between 0.4 and 0.7 microns. Electromagnetic waves of a few microns are said to constitute the "near infrared," that is, infrared radiation near to the visible region.) These observations should yield information concerning atmospheric circulation and cloud properties and may establish correlations with features on the surface of the planet. The investigation will employ Galileo's Near-Infrared Mapping Spectrometer (NIMS).

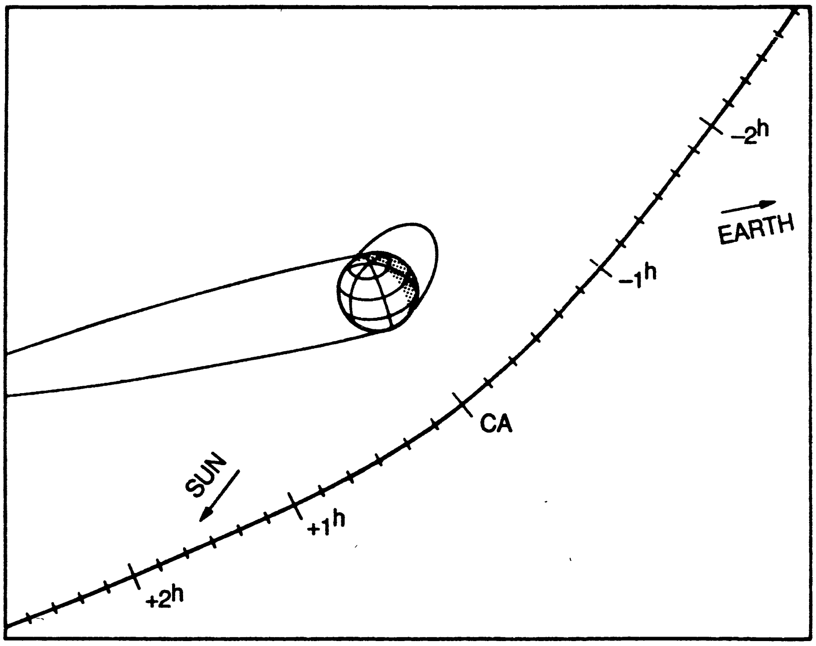
A second objective in the category of first-time science at Venus is to track atmospheric features (convection cells, eddies, etc.) moving in the midlatitudes and equatorial regions. Temporal variability at very short time scales will be determined while observing the features from Venusian morning to afternoon. The observations will be carried out with the spacecraft's camera — formally designated The Solid-State Imaging (SSI) subsystem. The NIMS will also participate in this scientific objective by hotspot coverage on the dark side of the disk.

Previous U.S. and Soviet missions to Venus have made measurements that indicate the possibility of lightning on Venus, but no strikes have ever been imaged. Science planners are computing the probability of observing lightning, based upon the number of SSI images which could be taken and the presumptive frequency of the phenomenon. The outcome will determine whether or not the optical detection of lightning is worth attempting at Venus.

One of Galileo's planned investigations at Venus employs a series of scans of the planetary limb with the spacecraft's Near-Infrared Mapping Spectrometer (NIMS)

NASA/JPL





Although the prime mission of Galileo is exploration of the Jovian system, the spacecraft will fly past Venus in February 1990 with the opportunity of conducting valuable scientific investigations. (The longer elongated zone at Venus represents a region, in the plane of the trajectory, where Earth would be occulted by Venus, the shorter zone shows the area of solar occultation.) *NASA/JPL*

Finally, in the category of first-time science, the NIMS will be used to conduct a program of spectroscopic measurements in the middle and deep atmosphere and to map the airglow phenomenon (at 1.27 microns and due to the recombination of molecular oxygen) which has been observed from Earth but not by previous space missions.

The durable Pioneer Venus Orbiter (Pioneer 12), managed by NASA's Ames Research Center, has been unlocking the secrets of Venus for over a decade. During Galileo's flyby, the two spacecraft will collaborate in achieving several scientific objectives: global (atmospheric) feature tracking, investigations of the mechanism of auroral excitation, magnetic-field measurements, and studies of particles and waves in the magnetosphere. In addition to the NIMS and SSI, Galileo's ultraviolet spectrometer and photopolarimeter will participate in the program of joint measurements along with several fields and particles instruments.

Venus has been a prime target for planetary scientists since the early days of space exploration — the Mariner 2 flyby of Venus in 1962 was JPL's first successful interplanetary mission — and numerous lines of investigation have been initiated with regard to the second planet. Galileo will contribute to this reservoir of research by corroborating and refining results in several areas including the energy budget of the planet (see the December edition of this column for similar studies for the outer planets); spatial variability of water, sulphuric acid, and sulphur dioxide in and above the clouds; planetary limb studies; nightglow in the ultraviolet; and cloud-top temperatures.

Dr. James A. Dunne is the chief of Galileo's Science Requirements and Operations Planning (SROP) team and is working with investigators on the Project Science Group and project engineers to formulate in detail the scientific plan at Venus.

The principal constraint on the development of this plan, according to Dunne, is the limited amount of space available on the spacecraft's tape recorder for the storage of observational data. Galileo's high-gain antenna must remain furled to protect it from thermal damage while in the inner solar system, and real-time communications must utilize one of two low-gain antennas. At the time of the Venus flyby, 1200 bits per second can be pumped to Earth through the low-gain antenna, and this will be devoted to engineering telemetry. Hence, scientific observations of Venus must be recorded on the spacecraft's tape recorder and played back many months later when Galileo draws closer to Earth.

The tape recorder has four tracks. One will be reserved for recording key engineering data, such as generated during spacecraft manoeuvres, to assist in the later analysis of any anomalies that might arise. The remaining three tracks will store the scientific data from Venus encounter with two tracks devoted to the category of first-time science.

The Venus encounter will span the period of one day prior to closest

approach to three days after that event. Normally, a planetary encounter poses severe problems for science planners in their attempt to fit all desired observations into a conflict-free timeline. But Dunne said the tape-recorder constraint is so severe that it restricts the allowable number of observations to the point that interleaving them in the time domain is relatively easy.

The encounter of Galileo with Venus is a bonus accruing from the long trek to Jupiter, but it is, of course, secondary to the primary mission of Jovian exploration. In recognition of this fact, two separate command sequences will be prepared for the period of time which includes the Venus flyby. The first will include scientific activities, as described above, while the second will only contain engineering activities conducive to the maintenance of the spacecraft in interplanetary cruise; the Mission Director will decide which sequence is to be uplinked to Galileo based upon an evaluation of the state of affairs in early 1990.

That Galileo has the opportunity to make unique contributions to Venusian science is a turn of events that would have seemed inconceivable just a few years ago.

German Space Operations Centre

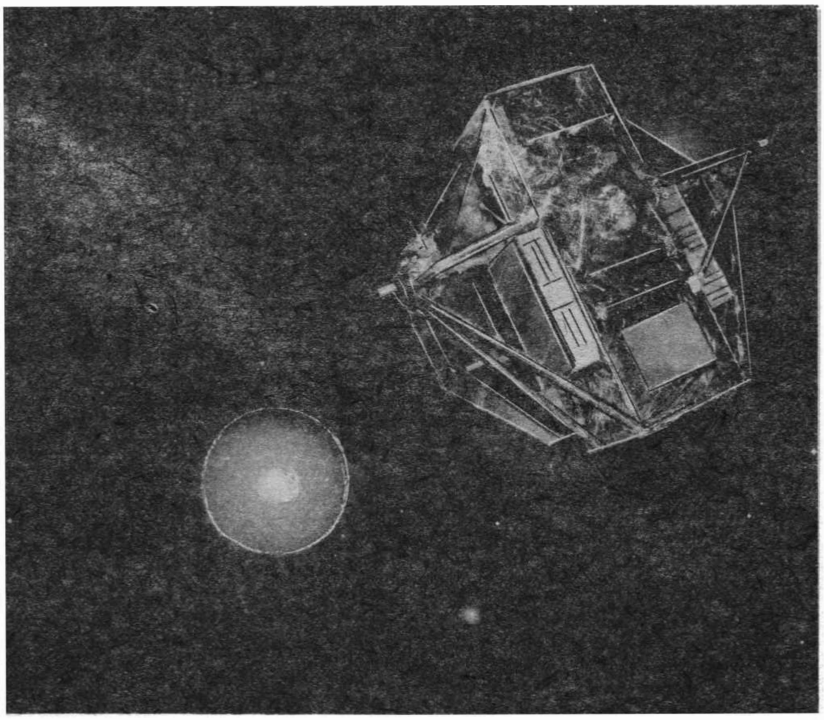
Driving through the Bavarian countryside on a sunny afternoon in early October furnishes a setting of great beauty, with the trees starting to colour and, nearing Munich, the white heads of distant Alps visible on the skyline. My destination was the German Space Operations Centre (GSOC), which is located in Oberpfaffenhofen about 30 km west of Munich. The 300-person staff of GSOC is contained within a larger DFVLR (Die Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt) facility of approximately 1000 people. DFVLR is the national space agency for Germany and has five field centres with headquarters in Cologne. Roughly one half of the German space budget is invested in national activities, and the other half supports projects of the European Space Agency (ESA).

The sunlight was especially welcome since I had come from a period of rain while visiting the European Space Operations Center (ESOC; see January's column) 300 km to the north, in Darmstadt.

The Director of GSOC is Dr. Franz Schlude, whose organization chart lists seven Divisions. The primary purpose of my visit was to confer with Hubertus Wanke, head of the Mission Operations Division for Unmanned Projects, which includes scientific spacecraft and communications satellites.

GSOC was established in 1968 and has supported a number of missions including Helios (two spacecraft in heliocentric orbit), the German-French Symphonie communications satellites, and AMPTE. Starting in the mid 1970s, there was a pause in the flow of new operational opportunities, but Spacelab and Galileo support have helped bridge the gap.

Currently, the only missions in flight are the Indian Remote Sensing satellite, IRS–1A, for which GSOC comprises the European node, and the damaged TV-SAT 1, which is used primarily for training purposes.



The celestial sphere will be surveyed in the X-ray and extreme ultraviolet regions of the electromagnetic spectrum by ROSAT. This astronomical satellite is scheduled for a 1990 launch and will be operated from the German Space Operations Center (GSOC) at Oberpfaffenhofen *Dornier*

The menu of future missions is as substantial and varied as the legendary cuisine of the region. (Necessary digression: hot Weisswurst from a stand in Munich's Viktualienmarkt is a gastronomic joy.) Geostationary satellites are TV-SAT 2 (1989), DFS 1 and 2 (Deutsche Fernmelde Satelliten) for the Bundespost (1989), and four communications satellites for Eutelsat (starting in 1990). Scientific Earth satellites are represented by IRS–1A and ROSAT (Röntgen satellite, 1990), and interplanetary operations are achieved through support of NASA's Galileo flight to Jupiter, which is scheduled for a 1989 launch.

The principal support to Galileo consists of receiving telemetry from the fields and particles experiments during the cruise to Jupiter. This tracking will begin once the spacecraft leaves the inner solar system (where it will receive a gravity assist from Venus), and the high-gain antenna is unfurled. Five passes per week are scheduled, using GSOC's station at nearby Weilheim. (The Weilheim station possesses two 15m antennas, S-band, and one 30m dish, X-band and S-band. The 30m antenna will be used for Galileo tracking.) In addition to capturing this scientific data during cruise, GSOC will merge the Weilheim portion with similar data gathered by NASA's Deep Space Network and distribute the resulting Experiment Data Records to investigators. Commands can also be sent to the Galileo spacecraft from the Weilheim station at the request of the control team at JPL.

Plans for manned space flight operations are quite extensive. The "D2" and "D3" Spacelab missions are scheduled for 1991 and 1993, respectively, while Columbus, the European component of the international Free-

dom Space Station, will be operated later in the 1990s.

My interest focused on ROSAT, and Fritz Guckenbiehl, the Mission Operations Manager, described the basic structure of the mission (see the August 1988 issue of *JBIS* for three technical papers on ROSAT). The satellite will conduct a six-month survey of the celestial sphere in the X-ray and extreme ultraviolet regions of the electromagnetic spectrum.

A feature of mission planning which may represent an important trend in operations in Europe and within NASA (the 1992 Mars Observer is a case in point) is the provision for remote scientific operation ("telescience") of the ROSAT scientific instruments from the Max Planck Institute in Garching. The scientists are responsible for generation of command files for the two instruments — an X-ray telescope and a wide-field camera for the extreme ultraviolet — and will deliver them to the GSOC control centre via data lines. The files can then be transmitted to the appropriate location in the data system of the spacecraft. Engineering control of the spacecraft, such as pointing commands and downlink of data to the tracking station, is retained as a function at the Oberpfaffenhofen site.

The integrated sequence of commands that ROSAT will receive from the ground will result from a blend of these scientific and engineering activities. Receiving inputs from scientific investigators as to what astronomical targets are desired for observation, the Mission Timeline Generator program at the GSOC control center will formulate an observing plan consistent with constraints such as interference from the Earth, Sun, and Moon. The computer program will utilize observer-supplied priorities to assist in construction of the observing schedule. Approach to optimization of the observing plan will be achieved by rerunning the Mission Timeline Generator until a satisfactory conclusion is achieved.

The actual sequence of time-tagged commands for ROSAT will be produced by another piece of software which will draw upon the mission plan and the above-mentioned instrument-control files supplied from scientific investigators at Garching (e.g., an instrument-calibration sequence). Guckenbiehl said that a sequence would usually be loaded onboard to guide activities for the next 24 hours, but, when possible, a 48-hour sequence would be uplinked to the spacecraft. Three years of orbital operations are planned.

Launch and early operations for a spacecraft are conducted from the Main Control Room. After commencement of the routine phase, the project migrates to a dedicated control room to be operated by a small staff, with experts on-call for anomalistic situations. I asked Herbert Wusten (who is the Flight Operations Manager for GSOC support of Project Galileo) whether they had considered using a multimission team for spacecraft control (JPL is pondering the same question). Indeed, they have discussed the multimission option but, so far, have concluded that conflicts during periods of intense activity and possible confusion between differing spacecraft properties rule in favour of the dedicated-control concept.

With its Spacelab experience, GSOC is slated to play a major role in manned-space flight operations in Europe. The Columbus programme consists of the Attached Pressurized Module (APM), the Man-Tended Free Flyer (MTFF) and the Polar Platform. The APM will be controlled from the U.S. with GSOC providing operations coordination of European experiments and serving as a single point of contact in Europe. With regard to the MTFF, however, control will be vested at GSOC, and a large Manned Space-Laboratories Control Center will be constructed for MTFF and APM support.

Lothar Bierling and Jürgen Fein briefed me on the range of activities planned for Columbus. Three modes of MTFF operation are envisaged: (1) automatic (analogous to the ROSAT task — generate a timeline, then produce a sequence), (2) teleoperated, and (3) crew supported. Generally, the MTFF would operate without human presence for six months, followed by a servicing visit by astronauts for about one week. Coordination of operations would revert to ESOC at Darmstadt during combined operations of more than one Columbus element, such as approach of the planned European spaceplane Hermes to the MTFF for servicing, but control of the elements would remain in the relevant control centres.

Perseverance has paid dividends for GSOC. Maintenance and steady development of capabilities have put them on the threshold of a period of strong growth as the tempo of European space activities increases.

SETI and the Supernova

The search for extraterrestrial intelligence (SETI) is an enterprise which derives considerable impetus from the fact that either outcome would be of absorbing interest. While logic's law of the excluded middle guarantees either the existence of intelligent extraterrestrials or the fact of our existence as the unique thinking substance of the universe, there is, unfortunately, no guaranteed method for rapidly resolving this dichotomy. The most common method employed in SETI is scanning for electromagnetic signals which could be interpreted to have been sent by intelligent extraterrestrials, and several such searches have been conducted since Frank Drake's pioneering effort — Project Ozma — in 1960.

The difficulties facing a practitioner of SETI trace back to two root problems: (1) the immense volume and variety of cosmic signals that must be sifted in the hunt for a glimmer of intelligent representation, and (2) the intended reference (meaning) that such a representation would contain.

A large number of proposed methods for coping with these problems have emerged in the past few decades. A popular approach is to assume radio waves are a likely carrier of incoming signals and search Sun-like stars for radio emissions. This strategy helps to narrow the size of the event space that must be searched, and a further contraction is achieved by emphasizing inspection of radio wavelengths in the neighborhood of the 21cm line emitted by interstellar hydrogen. This neighbourhood has been dubbed "the water hole" due to symbolic associations of the resident interstellar chemical species with the chemistry of water, a compound so important to terrestrial life. In addition to advantages relative to both of the root problems of SETI, the water hole confers the technical benefit of being located in a region of minimum background noise in the radio spectrum. (The book *Communication with Extraterrestrial Intelligence (CETI)*, MIT Press, 1973, edited by Carl Sagan, treats the water hole and other aspects of "classical" SETI with insight.)

The NASA SETI programme, begun in 1983, is addressing the "volume and meaning" problems through construction of a balanced search strategy which employs both an all-sky survey over a broad range of frequencies and a more focused and sensitive search in selected, preferential domains. The programme is reviewed in the April 1986 edition of this column.

Although one can readily understand the difficulty of sorting through large amounts of data, the second problem, recognizing and interpreting a SETI datum when it is presented, is not as easy to appreciate. In an attempt to enhance this appreciation, three examples will be given of the vice of subjectivity and the way in which it con-

stricts our views of the wide world and its potential inhabitants.

We commonly view bacteria as single-celled organisms. Writing in the June 1988 *Scientific American*, J. A. Shapiro describes complex multicellular structures and functions associated with certain bacterial colonies. He claims that our view of these creatures as unicellular persists because of our subjective focus on their role as agents of disease.

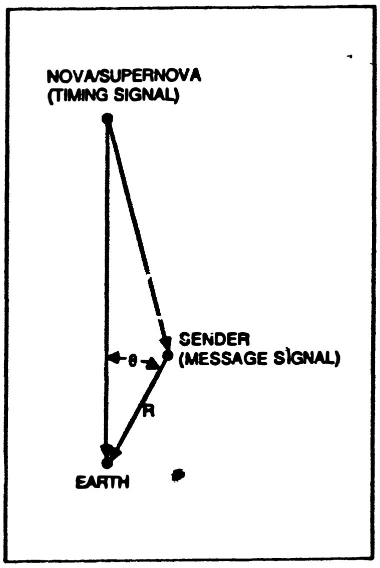
A second, more complex example can be developed through considering Dr. Paul D. MacLean's theory of the triune structure to the human brain. MacLean, Chief of the Laboratory of Brain Evolution and Behaviour, National Institute of Mental Health, has elaborated an anatomical and functional view of our brain which identifies three components: an old reptilian-based formation, a more recent mammalian "limbic system", and the most evolutionarily recent contributions of the neocortex. The two older components are not only a part of our neural machinery but also possess their own, unique, subjective viewpoints. According to MacLean, the reptilian brain is a factor in mass hysteria and mob violence and "behaves as though it were neurosis-bound by an ancestral superego," while the limbic system "might be likened to a primitive television screen giving the mammal a better picture for adapting to its internal and external environment". (See p. 12 of MacLean's *A Triune Concept of the Brain and Behaviour*, U. of Toronto Press, 1973.)

The theory, as it stands, provides a biological complement to psychological analyses (like those of Freud) of the individual unconscious and once more demonstrates how difficult it is to recognize the stranger in our midst. Continuing to mine the same vein and taking a cue from MacLean's finding that the limbic system has access to substantial information, including visual, about the external world, might we not presume the possibility of interaction between the limbic systems *per se* of different humans?

The idea of a "Limbic Society" with its own practices and institutions as a shadowy presence coexisting with our human civilization seems fanciful and even a bit eerie, but it might supply the physical setting for Carl Jung's (1875–1961) notion of the "collective unconscious." Consider that the familiar mechanisms of human interpersonal communication are not directly neocortex-to-neocortex but require passage through intervening systems of organic and inorganic material in a most complicated manner. Could not interlimbic communication similarly prosper?

From the perspective of the Limbic Society, the community of our upper-brain faculties would not, we hypothesize, be recognized as such. Instead, it would constitute a set of constraints and rules — laws of nature — to be accommodated in the best way possible, e.g., Freud's theory of the coding of dream material to evade upper-brain censorship. The basis for this assertion is that our higher constructions would lie beyond the ken of the limbic system (which is nonverbal), and it would only be feasible to reduce perceived regularities to rules. In short, the Limbic Society might recognize no higher form of life inhabiting its world, barring a successful search for extralimbic intelligence!

The two preceding examples, bacterial colonies and my postulation of the problematic Limbic Society, have dealt with entities below us in the evolutionary chain. Dr. James Lovelock began to speculate on planetary life during his stint at JPL as a scientist for the Viking expedition to Mars, a project primarily devoted to the search for extraterrestrial life. Since then, Lovelock has developed and championed the hypothesis that the Earth, taken as a whole, is a living organism: the Gaia hypothesis (Gaia was the Greek goddess of the Earth). But he does not claim a human-like consciousness for Gaia.



The occurrence of a bright nova or a supernova furnishes a timing pulse that can serve to synchronize sending and receiving activities for an interstellar message. The message is sent when "Sender" first observes the celestial explosion, and then "Receiver" tries to detect the message $R(1-\cos\theta)$ years after observing the explosion at Earth (R is the distance in light years from Earth to Sender, and the distance to the nova or supernova need not be known provided it is large compared to R).

NASA/JPL

The Gaia hypothesis rests upon what Lovelock asserts is purposive behaviour of the Earth in maintaining the existence of the biosphere in the face of great adversity. He claims, for example, that the stability of the temperature of the atmosphere over thousands of millions of years could not have been achieved by a simple physico-chemical system's reactions. The evidence is skilfully marshalled in his latest book, *The Ages of Gaia* (W.W. Norton, 1988).

As in the case of the Limbic Society, we are not concerned so much with the truth of Gaia as with the deficiencies it illustrates in our cognitive faculties; Gaia, for this purpose, is a thought experiment — a stimulus to the imagination — that puts us in the analogous position of a limbic system trying to comprehend a complex environmental entity. In other words, the Gaia concept presents a possible instance of an epistemological limit; if Gaia were true, could we expect ever to know that fact? Would it be more advanced than us? Less advanced? Not comparable?

In February 1987, a naked-eye supernova was observed in the Large Magellanic Cloud and was the brightest supernova to be observed since 1604. (See the September 1988 "Space at JPL".) The employment of astronomical explosions in SETI was analyzed in my December 1977 paper in *Icarus*. In brief, explosions, novae or supernovae, can serve as celestial clocks (albeit with one tick and no tock) to synchronize the communcation efforts of sender (the extraterrestrial for the case of greatest interest) and receiver (us). The clock principle states that the sender transmits a message upon observing the celestial explosion. We can then calculate how much later than *our* observation of the explosion the message would arrive. The calculation only depends upon the speed of light and the relative geometry of sender, Earth, and exploding star.

Just as the water-hole convention narrows the wavelength domain to be searched, the clock convention narrows the time domain, when a clock is available. The bright nova in Cygnus in 1975 furnished the material for construction of a celestial clock, and some observational opportunities were discussed in the July/August 1986 edition of this column.

The theory is equally applicable to the 1987 supernova, and, applying the simple calculations prescribed in my *Icarus* paper to the nearby Sun-like stars Tau Ceti and Epsilon Eridani, it is found that the prime observing time for signals from the former ranges from June 1993 through January 1994, while the latter's range is November 1992 through February 1993. A span of time is given in each case because of uncertainties in the distances of these two stars (the calculation is relatively insensitive to the exact distance of the supernova). For further candidate stars, the SETI practitioner is advised to utilize W. Gliese's *Catalogue of Nearby Stars* (1969 — but a new edition is in preparation). The stars Tau Ceti and Epsilon Eridani are fabled in SETI lore and, in fact, were the two examined by Drake in 1960.

The clock convention (like the water-hole convention) addresses the two root problems of SETI: reducing the volume of data to be gathered and establishing a common occasion of reference for sender and receiver.

The reduction in the time domain that must be searched for a signal is easily calculated if we assume that a supernova occurs in the galactic neighborhood about once every 100 years. Ratioing this time period to the above-mentioned (uncertainty) time ranges yields a reduction factor of about 150 for Tau Ceti and 300 for Epsilon Eridani.

The preceding discussion on epistemology indicated that organisms of greatly differing capabilities probably do not share cognitive domains to any appreciable extent. The idea behind a convention like the clock principle is to throw the burden of insight onto the more advanced entity — presumably sender in this application — and hope that it guesses exploding stars are objects of temporal significance to planetary dwellers at our stage of evolution. We would be hard pressed to guess what might attract the attention of Gaia (with its slow time scale) or its ilk.

The goal of SETI is, of course, contact with intelligent life beyond our planet. We do not know when such an event might come to pass, if ever, but the literature of the subject shows steady progress in our grasp of methodology. An important by-product of SETI, with or without "first contact," appears to be insights we gain concerning human nature and its place in the cosmos.

MISSION REPORT

V27

Ariane 4 Goes Commercial

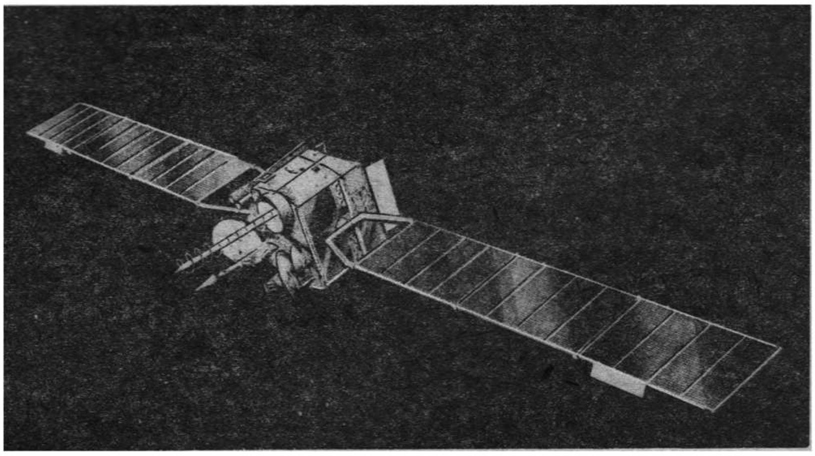
The first commercial Ariane 4 blasted off from the Guiana Space Centre carrying the Skynet 4 and Astra satellites. The satellites were successfully injected into a Geostationary Transfer Orbit (GTO) less than 18 minutes after launch. This is the second flight for Europe's most powerful launcher, the Ariane 4. The vehicle was first tested in June 1988 (*Spaceflight*, August 1988, p.304).

The Ariane 4 was launched from pad ELA 2 at Kourou on December 11, 1988 at 00:33:38 GMT. The Ariane 4 was equipped with two solid and two liquid strap-on boosters (an Ariane 44LP). The launch was threatened by bad weather, but the storm clouds cleared and the countdown went ahead. A launch the previous night had to be aborted when problems with the third stage engine sensors were detected.

Provisional parameters calculated for the injection into GTO were:

Perigee: 202 (+/−1)km for 199.8km intended
Apogee: 36,200 (+/−100)km for 36,010km intended
Inclination: 7.06 (+/−0.05) degrees for 7.00 degrees intended.

Frederic d'Allest, Arianespace Chairman, declared. "Arianespace is especially proud tonight to have launched successfully and simultaneously one satellite for the UK Ministry of Defence as well as the first private European satellite for the 'Société Européenne des Satellites' of Luxembourg. For Arianspace this represents the inauguration of commercial services with the new generation of Ariane 4 launcher. Flight 27 is also the seventh launch in 1988 and establishes a new record launch of 16 satellites into precise Geostationary Transfer Orbit in the past 15 months."



An artist's impression of the British Ministry of Defence communications satellite, Skynet 4.
BAe

Skynet 4B

Skynet was built by the Space and Communications Division of British Aerospace, with Marconi Space Systems responsible for the communications package.

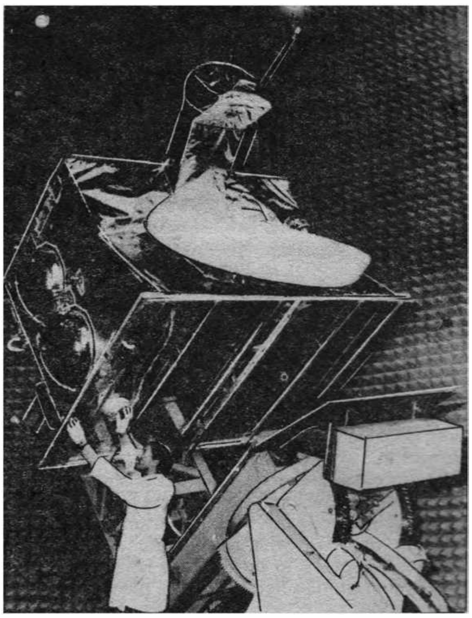
Once in position, at 1 degree West, the spacecraft will provide the UK's armed forces with a radio relay in space with greatly increased strategic and tactical communications and improved anti-jamming capacity. Skynet's antennae provide a variety of footprints ranging from spot to global coverage.

The Skynet 4 system consists of the satellites, or space segment, and the ground segment, which is composed of various fixed and transportable ground station on land and at sea. The system will provide communications between these stations on the SHF band for surface vessels and land stations. Communications to submarines will be by UHF. The satellites will be monitored and controlled from the main control centre in the UK using X-band and S-band transmissions.

Skynet 4 was originally scheduled and designed for launch aboard the US Space Shuttle, which would have also carried the first Britain in space. The disruption to the shuttle schedule caused by the Challenger accident resulted in the modification of the spacecraft for the launch by Ariane 4.

Skynet 4 is the first dedicated military payload to be launched by Ariane. The second Skynet 4 is scheduled for launch by Titan 3 in August 1989 and the third for launch by Ariane 4 in May 1990.

Astra 1A



The Astra satellite belongs to the Société Européene des Satellites (SES), a private company incorporated in Luxembourg.

Astra is to be located in geostationary orbit at 19.2 degrees East. It has 16 operational transponders, each of which retransmits a television channel, and six spare or redundant transponders. These spares provide for an in orbit back-up for Astra's television channels.

Each transponder on Astra has 45W of power output. The satellite has been designed so that its footprint, the geographical area within which signals can be received, is shaped to cover the areas with the highest consumer purchasing power of Western Europe. In the area of Astra coverage in which the television signal has a power of 52dbW it will be possible for a television viewer to install a parabolic reception antenna (dish) as small as 60cm in diameter, and a tuner attached to an existing television set, to receive high quality television signals. Viewers outside this area will have to use progressively larger dishes.

The Astra 1A satellite during pre-flight tests.
Arianespace

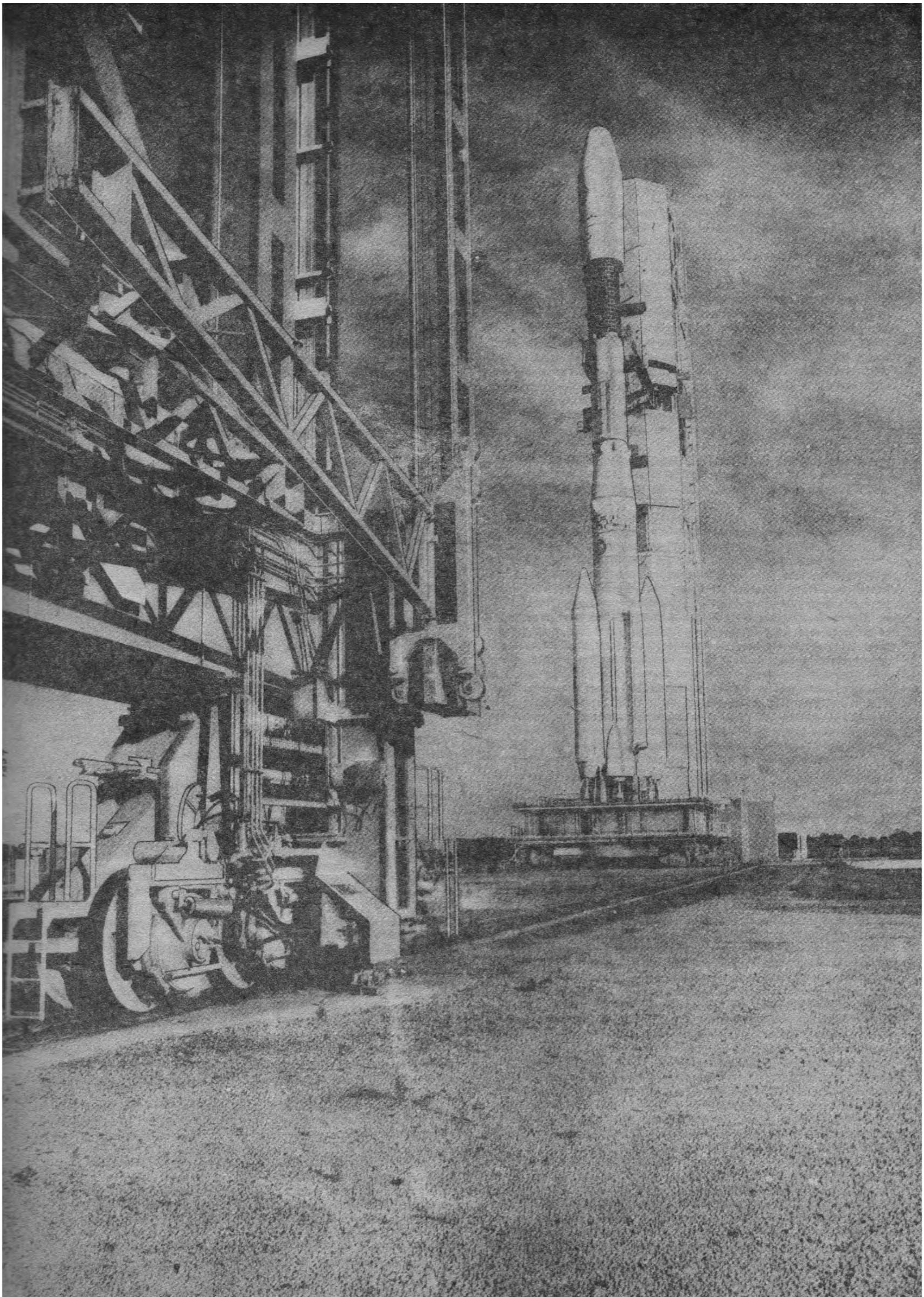
Ariane V28 Success

Ariane V28 was launched on January 28, at 01:21 (GMT); the tenth successive flight since September 1987.

The Ariane 2 blasted off from launch pad ELA-2 at the Guiana Space Centre, Kourou. 16 minutes later the launcher placed the 15th, and final, Intelsat V communications satellite into a Geostationary Transfer Orbit. The satellite can handle 15,000 simultaneous telephone calls and two colour television channels. In September an Ariane 4 will launch the first Intelsat VI.

The next launch is scheduled for February 28. An Ariane 4 is to orbit the Japanese communications satellite, JC-SAT 1 and the European Meteosat (MOP) 1.

Ariane V27 stands poised for launch at the Guiana Space Centre, Kourou.
Arianespace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BOOK NOTICES

Schirra's Space

W.M. Schirra Jr, with R.N. Billings, Gazelle Book Services Ltd. Falcon House, Queen Square, Lancaster, LA1 1RN, 1988. 227pp, £12.50

The history of space research in the US has been absorbing, if not sometimes controversial, from the earliest days and reached a fever of excitement with the manned Apollo flights to the Moon.

This book is the autobiography of the only astronaut who participated in all three pioneering manned space programmes, i.e. Mercury, Gemini and Apollo. It takes us almost into the inner sanctum of the US space programmes, to learn at first hand about the intense competition which took place at every stage of the process as well as the rigorous training which each astronaut had to undergo and thus provides a chronicle of an important era in space history by a major participant.

The co-writer named on the cover is a professional writer who has already "ghosted" other personal stories about American astronauts and their wives.

Introduction to the Space Environment

T.F. Tascione, Orbit Book Co. Inc., P O Box 9542, Melbourne, FL 32902-9542, U.S.A., 1988, 116pp, $34.50.

Our understanding of the near-Earth space environment has grown rapidly over the last twenty years or so as a result of the detailed measurements returned by increasingly sophisticated orbiting satellites. This book summarises complicated, and sometimes conflicting, theories that have been derived from such measurements and presents them in a clear and readable fashion.

The book is organised into 10 main chapters which review plasmaphysics and solar physics, the formation and dynamics of the solar wind and interplanetary magnetic fields, the structure and origin of the geomagnetic field and its interaction with the solar wind. An understanding of the structure of the neutral atmosphere is basic to understanding the atmosphere, for neutral winds are very important in determinging the dynamics of the lower ionosphere. Further discussion on the interaction between the ionosphere and magnetosphere follows, concluded by final chapters which look at relevant ground-based and space-based systems.

The Harlow-Shapley Symposium on Globular Cluster Systems in Galaxies

J.E. Grindlay & A.G. Davis Philip. D. Reidel Publishing Co., PO Box 989 3300 AZ Dordrecht, The Netherlands. 1988. 751pp, £85.00

This volume is intended to highlight the large-scale properties of globular clusters during their formation and evolution in galaxies. It reviews some of the recent spectacular progress and prospects for the future study of globular clusters, whether in our own or in external galaxies and looks forward to the prospects for further discoveries which will emerge with the use of the Hubble Space Telescope.

The book is in honour of Harlow-Shapley, an astronomer who first noted the concentration of globular clusters in the sky in 1915 and which, by 1917, had enabled him to locate the position of our solar system far from the gala tic centre. Actually, the attempt to produce a three-dimensional model of the Milky Way goes back much further, and to a most unlikely origin viz. William Stukeley, who proposed to Isaac Newton on one occasion that the Sun and the brightest stars of the night sky made up what we would today term a globular cluster, surrounded by a gap outside of which lay the other stars of the Milky Way in the form of a flattened ring. Stukeley's remarkable suggestion is recorded only in his memoirs so, unlike the work of Harlow-Shapley, it had no effect on the subsequent history of astronomy.

Much of the book records the remarkable advances in observations made possible with CCD detectors and the ready availability and use, nowadays, of desk top computers to help with both data analysis and theoretical modelling. Specific topics deal with the discovery of what appears to be a correlation between cluster metallicity and the slope of the luminosity function of its stars as well as comprehensive studies of the globular clusters in the Magellanic Clouds, M 31 and Local Group Galaxies. The evolution of globular clusters past their stage of core collapse and the possibility for re-expansion and tidal disruption are also considered, with the disruption aspect expanded to include tidal shocks in the galactic disc and encounter with giant molecular clouds.

Space Nuclear Power Systems 1986

M.S. El-Genk & M.D. Hoover, Orbit Book Co. Inc., P O Box 9542, Melbourne, FL 32902-9542, U.S.A., 1987, 482pp.

This volume, reproducing 45 papers, is based on a meeting held in Albuquerque, USA in January 1986, the object of which was to summarise the current state of knowledge of nuclear power systems and to provide a forum where the most recent findings could be presented. The text is, therefore, very wide ranging. It discusses the possibility of using nuclear power to open new vistas in space exploration as well as examining the power requirements for a number of proposed future missions. Safety, of course, is a critical issue and one which is also considered, particularly to avoid a repetition of the sort of re-entry problems which have provided such adverse publicity in recent years.

Much of the volume is concerned with the characteristics of space nuclear power reactors, i.e. problems of designing, simulating and testing as well as thermal management in space. Progress in the development of energy conversion systems, including the analysis of transient behaviour and the development of fuel cells, is also considered.

The question of materials technology for such things as superconductors and insulators and the suitability and performance of various refractory alloys for use in a space reactor environment is crucial. Expert systems for developing space power supplies and the user-interface are analysed.

Radiation damage is a problem which might prove acute, hence the inclusion of an examination of mechanisms for dealing with breakdowns, including ground-based reactor testing.

Large Space Structures: Dynamics & Control

Eds: S.N. Atluri & A.K. Amos. Springer-Verlag GmbH & Co KG, Heidelberger Platz 3. Postfach. D-1000 Berlin 33, Germany, 1988, 363pp Hard Cover DM 148.

The aim of this monograph is to summarise the present state-of-the-art as it applies to the technologies of the dynamics and control of large space structures.

Considerable activity on a world-wide scale has developed over the last decade in getting to grips with the need to establish a suitable technical base for such systems. Work has ranged from systems concept studies and laboratory experiments to preliminary flight experiments The objectives have been to establish the interaction between large space structures and the space environment. e.g. as regards durability of materials and devices. assembly and repair operations and the dynamic behaviour of the structures themselves.

It is this last area which provides the prime basis for this book, with its clear emphasis on basic analytical experimental methods

Among the main themes considered are the development of models for beam-like and plate-like lattice space structures and the resulting problems of dynamics and control. This latter includes such matters as vibration, friction between contacting surfaces and how non-linear dynamic motion may be controlled with the use of active and/or passive mechanisms.

A Catalogue of Southern Peculiar Galaxies and Associations

H.C. Arp, B.F. Madore & W.E. Roberton, Cambridge University Press, The Edinburgh Building. Shaftesbury Road, Cambridge, CB2 2RU, England, 1987, 2 Vols £80.00)

Galaxies do not exist in total isolation. They interact with their environments and modify their surroundings through nuclear activity, galactic winds. tidal encounters and collisions. Although not necessarily continuous phenomena. the effect of all these factors on the long-term evolution of galaxies must undoubtedly be significant. The galaxies we see today are the accumulated result of both quiescent and catastrophic evolution.

The purpose of this catalogue is to highlight the most spectacular phases of such evolution. and possibly galactic formation, by attempting to identify and to set out in basic form how all these activities have or are being manifested.

It is not enough to catalogue individual galaxies: the identification of galactic-associations is also important and here the UK wide-field Schmidt Telescopes in Australia have come into their own by providing a new perspective, unavailable earlier. in making pairs, triples and clusters of galaxies immediately apparent besides, incidentally, making whole sky surveys possible.

The matenal thus available has been used as the source for compiling, for references purposes. this detailed catalogue of all the interesting

galaxies and of most striking (apparent) association of galaxies detected in the Southern sky.

Volume I is largely tabular in character. Following a short introduction, it lists and describes each galaxy in turn, indicating its position, apparent appearance and the relevant identifying photographic plate.

Volume II consists almost solely of photographs. These provide representative examples of galaxies falling within the various categories adopted for the Vol.I classification scheme. Naturally, the largest and most spectacular examples have been included but so have many others to show a morphological transition and continuing progression towards later categories.

All the Galaxies listed deviate significantly from equilibrium forms and show disturbances in the form of jets, distortions in shape or the existence of bridging material The cause, in most cases, seems to be small near-by galaxies which either cause the distortion or which, themselves, are being distorted.The classification scheme adopted is really empirical. It has been made simply from a visual inspection on the presently-available plates and could well be amended in the light of further investigations.

Cooling Flows in Clusters and Galaxies

A.C. Fabian, Kluwer Academic Publishers Group, PO Box 9889, 3300 AZ Dordrecht, The Netherlands, 1988, 391pp, £54 00

The use of x-rays some 20 years ago enabled astronomers to discover the diffuse gas existing within glactic clusters and led, subsequently, to the realisation that the central gas density in some clusters, and in elliptical galaxies, may be so high that radioactive cooling time decreases rapidly towards the centre of a cluster or galaxy. The result indicates a cooling flow which suggests that mass is being deposited in some clusters to the tune of several hundreds of solar masses per annum.

The implications of this are profound because it indicates that there is an on-going star formation within the centres of galaxies. This makes the subject of cooling flows of immense interest in understanding star formation, though other evidence appears to suggest that these deposits produce very low-mass stars or other dark matter. If this is so, it offers an insight into the origin of at least some of the dark matter in the universe and of the envelopes which surround some giant elliptical galaxies.

This is an area where there are still many unknowns and where there is still room for lively debate, as nearly fifty highly-specialised contributions here amply testify.

Astronomical Ephemerides: 1989

Masson, 120 Boulevard Saint Germain 75280 Paris, Cedex 06, France, 1988, 312pp, 150F

This book is an annual publication of the mathematical department of the Bureau des Longitudes which undertakes research in the field of celestial mechanics and basic astronomy.

The opening chapter provides data on the various events in the almanac and the civil and religious festivals arising. The two succeeding chapters contain astronomical definitions (systems of coordinates; time scales etc). The following chapters, indicating how the ephemerides are used, constitute the major part of the book. Explanations are given for the calculation of sunrise and sunset times, star setting times, the duration of a particular day, twilight periods and the time at which a star crosses the meridian.

These accurate mean ephemerides are provided for the Sun, the Moon, planets, asteroids, comets and for the major satellites of Jupiter and Saturn. Data required for the observation of the surfaces of the Sun, Moon, and planets and the shape and size of the four large satellites of Jupiter is supplied with the necessary explanations

Finally, the ephemerides of bright stars, double stars, star clusters, nebulae and galaxies are included together with data on astronomical phenomena such as eclipses of the Sun and Moon, star and planet occulations by the Moon, conjuctions, oppositions etc.

Orbital Motion

AE Roy, Adam Hilger, Techno House, Redcliffe Way, Bristol, BS1 6NX, England, 1988, 53299, £15.00 (Paperback).

This is the third edition of a comprehensive textbook which deals with the analytical methods of classical celestial mechanics, the recent numerical experiments into the orbital evolution of gravitating masses and the astrodynamics of artificial satellites and interplanetary probes. It requires little or no prior familiarity with astronomy or space science but does require a knowledge of calculus and elementary vector analysis. Problems, with answers, are included as are appendices of relevant astronomical and mathematical data. This text is intended primarily for postgraduate and advanced undergraduate students but its discussion of orbital computation will be of interest to serious amateur astronomers.

This edition includes new data about various bodies in the solar system, particularly relating to the systems of Jupiter and Saturn. New results from recent work on the stability of the solar system and its sub-systems have also been included, thereby enabling the text to be updated throughout.

The Wonderful Apparition: The Story of Halley's Comet

R.B. Peterson, Univelt Incorporated, PO Box 28130, San Diego, California 92128, USA, 1985, 195pp, $18.95

This book traces the history of one of the most interesting celestial objects from antiquity to the present. It details the fascinating story of the contributions made by generations of scientists who contributed towards understanding the nature of comets generally and to identifying the special place held by Halley's Comet particularly.

Bioastronomy - The Next Steps

G. Marx, Kluwer Academic Publishers Group, PO Box 989, 3300 AZ Dordrecht, The Netherlands, 1988, 434pp £69.00

Even though the potential rewards, or potential hazards, arising from a successful search for extraterrestrial intelligence may be great we are, at present, still groping in the dark for ideas on how best to conduct such a search.

This volume presents an abundance of stimulating, if not provocative, ideas about how such a search might be prosecuted, as well as providing a summary of the progress made over the past few years in the search for extra-solar planets and radio signals from outer space.

The most remarkable development in recent times has probably been the number of projects aimed at detecting the existence of planets around other stars. Significant improvements in instrumentation have brought this possibility well within reach and, if proved successful for some of the nearer stars, will undoubtedly show that planetary systems must be abundant throughout the galaxy. At the same time, sophisticated equipment and techniques under development will greatly enhance the search for radio signals and result in an effort which will dwarf previous work.

The present volume is divided into a number of major sections which cover such things as clues to the habitability of other worlds available within the solar system, and the search for extraterrestrial civilizations on the one hand the primitive life on the other. The question of alternate biologies also arises, i.e. will we recognise different life forms when we see them? There is the further question on whether intelligence arises inevitably in the evolutionary scale and, if it does, what are the prospects then for detecting other technological civilizations?

The book concludes with a short section on attitudes to be adopted if other civilizations are detected. In that event, it will undoubtedly give rise to wide-ranging responses. For example, *who* will respond - and on behalf of *whom?* Should it be a political,scientific or philosophical response - to indicate just some of the possibilities - or will it actually be made off-the-cuff by someone who represents nobody but himself?

We still have a long way to go in resolving such questions.

The Motion of the Moon

A. Cook, Adam Hilger, Techno House, Redcliffe Way, Bristol, BS1 6NX, England, 1988, 222pp, £35.00

The passage of the Moon across the night sky has long been a familiar, but mysterious, sight. Newton, with his Laws of Motion and Inverse Square Law of Gravity, was able to predict all the planetary orbits - at least in principle, but the theory of the lunar orbit was one which, he says, gave him a headache. In the event, an exact solution of the Moon's motion in the gravitational fields of the Sun and Earth defeated both Newton and his successors, even though complex analytical methods have since been evolved which give very good approximations. More recently, the advent of modern computers has allowed even more accurate numerical calculations to be performed. Radar observations of the distance of the Moon followed by lunar laser ranging and very long base-line interferometric observations made possible by the Apollo landings have outdistanced theory and set a further challenge. Even the predictions of general relativity can now be tested with greater precision.

This book provides a comprehensive account of all these theoretical developments over the past three centuries and up to the present time Although there is much good reading matter, fair knowledge of mathematics is also required.

SOVIETS in SPACE

Above the Planet

Salyut EVA Operations

Regular *Spaceflight* correspondent Neville Kidger continues his review of spacewalks made from the Soviet Union's Salyut series of space stations.

By Neville Kidger

First unscheduled EVA : August 15, 1979

The third EVA from Salyut 6 came at the very end of a six-month-long mission that would have seemed to have had its share of problems already.

Vladimir Lyakhov and Valeri Ryumin had already isolated a leaking fuel tank when the Soyuz 33 spacecraft, carrying Nikolai Rukavishnikov and Bulgarian Georgi Ivanov, experienced an engine problem during the final approach to the station. The two men narrowly escaped being marooned in orbit and returned to Earth after a flight of just two days.

This forced cancellation of a Soviet / Hungarian visit to Lyakhov and Ryumin. The Soyuz 34 spacecraft, which would have carried the visitors arrived at Salyut unmanned.

The final month of the mission witnessed a major first for the Soviet space programme with the deployment of a ten metre diameter radio telescope dish – the KRT-10.

There are suggestions that the telescope dish did not open fully when it was deployed after the separation of the Progress 7 cargo ship which delivered it.

After a month-long series of joint observations with a Soviet Earth-based radio telescope the time came to jettison the assembly. On August 9 the command was given. Ryumin described how he had activated the separation mechanism and watched on TV expecting to see the dish pushed away by pyro-bolts and springs. The dish, however, did not separate.

Ryumin later wrote that examination through a porthole and by TV showed that the wire dish had become entangled in a beam of the docking target. "If it were left there, the station would not be able to fly unmanned, as its orientation system would not work. We tried rocking the station, but to no avail. We could only spill out our emotion in the most impressive words we could find to address the bloody thing."

Ryumin outlined the stark choice : leaving the dish as it was, then thus abandoning the station ("for what had we kept it so spick and span, done all the necessary repair work and replaced the worked-out instruments with new ones?") or going outside to try and free the recalcitrant dish.

"The protective suits were two years old and had twice been used," Ryumin wrote. "Besides, work in open space was a great strain, and we were just out of practice, what with our half-a-year in weightlessness."

Nevertheless, the decision was taken to go outside. Aleksei Yeliseyev spoke to the two men. The veteran cosmonaut, who made his EVA in 1969, told the men they had done their duty and said they might refuse the task. But Ryumin wrote that they "would not listen, and began discussing the job in detail."

Ryumin confirmed that the men transferred into Soyuz 34 the equipment that they were to bring back: films, tapes, plants in ampoules and samples of alloys obtained in the furnaces in case they were unable to return to the station. James Oberg has said that both men wrote last letters to their families.

On August 15 both men ate dinner and began to don their undergarments and the main spacesuits. Ryumin described his donning: "It wasn't a picnic for me, with my six foot two height, and Vladimir had to push me into my suit."

Once sealed in Salyut's forward transfer compartment the air was vented. When the time came to open the hatch Ryumin radioed worrying news: the hatch was stuck. Both men applied pressure and finally, a minute late, Ryumin was able to open the hatch. It was 1416 GMT.

Ryumin "saw the sunlit Mediterranean far below, and felt some force – not wind – suck me out." Viktor Blagov, a deputy flight controller, radioed up to tell the men to be calm. "Quiet," Ryumin admitted saying to himself, "meaning it first of all for my wife. I knew she would be beside herself with fear." His heart rate was reportedly 134 beats per minute.

Ryumin stepped out and stood on the skip-plating holding a handrail. He watched the grandeur of an orbital sunset. With the EVA already behind schedule and the station in orbital darkness the two men were instructed to wait for the sunrise. Ryumin said that he saw floodlit cities in Japan and "if I had ever visited Tokyo, I might have recognised its main streets."

The station passed over the Pacific Ocean. The night was moonless. Ryumin said the wait, holding onto the handrail, made him feel like a man on the footboard of a crammed bus.

This Soviet stamp illustrates the daring spacewalk by cosmonauts Lyakhov and Ryumin to remove the KTR dish jammed in the Salyut 6 rear docking port.

The men were struck by the beauty of the stars. "They look like huge diamond pins on the black velvet," Ryumin said. He felt he could stretch out and hold one in his glove.

"In about half an hour, a bluish-green streak of light appeared on the line dividing Earth and its atmosphere. It grew broader and broader, and soon shone with all the colours of the spectrum. The Sun was about to rise," wrote Ryumin. "It was time to begin."

Ryumin, attached to the hatch with a safety line, began moving down the length of the station. Lyakhov came outside the station to inform Ryumin about the behaviour of the dish and, if needed, drag his comrade back in with the tether "if the worst came to the worst."

"I reached the station's tail and saw that the antenna was caught in several places instead of one, as we had thought," Ryumin wrote. "Its metal spikes had torn the soft skin plating. Quite a bit of work for me." At that moment the station was out of contact with Earth. Consulting Lyakhov, Ryumin decided to cut the four steel cables by which the dish was held. Ryumin had to be careful – the dish might well cover him like a net.

Oberg described how Ryumin tried to shield his eyes from the Sunlight by lowering his visor but had to raise it again when condensation from his rapid breathing caused the inner part of his faceplate to cloud over. He had to work with "sweat-soaked eyes."

"Full of apprehension, I approached the first cable, taut and as stiff as a poker, chose the necessary tool- . . . took aim. . . click! and it was cut in two," said Ryumin. There was no sound but the dish shook and moved towards the flight engineer prompting a call from Lykahov: "Look out! To the right, quick."

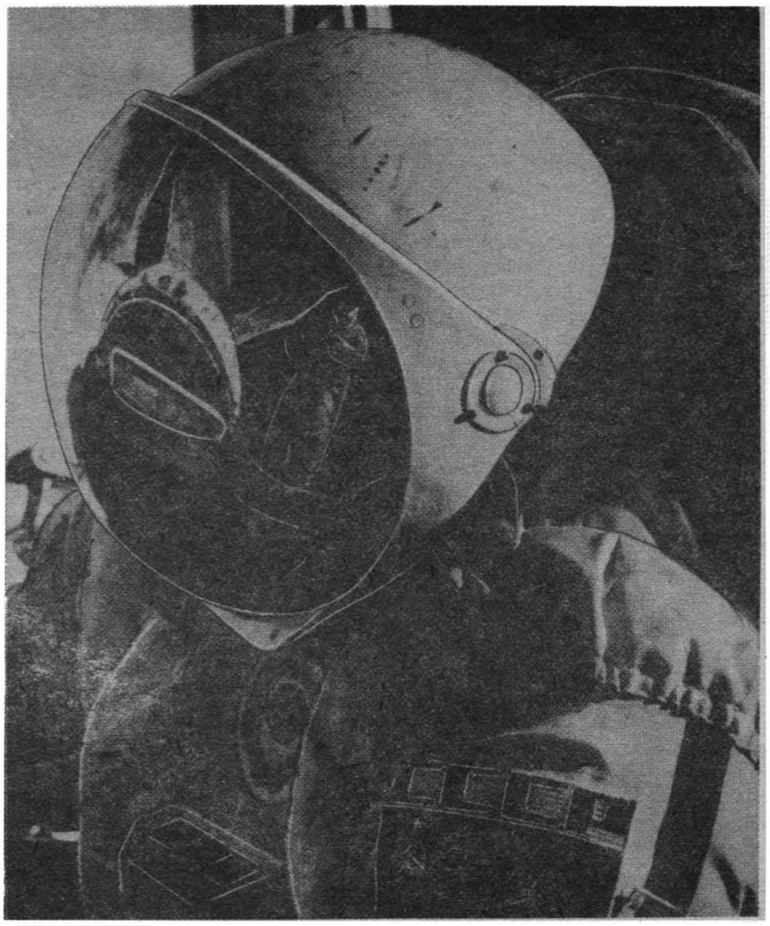
"I had a narrow escape this time," Ryumin reflected. When the dish stopped vibrating Ryumin cut another cable and the dish moved again, but in another direction. He then cut two other cables quickly "I was now a dab hand at it."

Ryumin then rested for a while before using a long forked stick to push the dish away from the station towards Earth.

Ryumin looked back at the station; he reflected that the job had seemed too easy "so I must be in for trouble. I made up my mind to examine the entire station from the outside. It looked well-worn, with the skin-plating faded and ragged in some spots."

He wiped a porthole with a piece of cloth and put it in his pocket. He knew experts on Earth would welcome samples of the dust. Ryumin also took samples of the plating added to the station by Kovalenok and Ivanchenkov for return to Earth.

At that point communications were restored with the control centre. "Of course, they had been on tenderhooks. We reported that the antenna was gone; no reply. They could not believe their ears; we were so far ahead of schedule," Ryumin said. "We said once more that the antenna was removed and we were on our way back, and had almost reached the entrance to the station. The control centre reacted with thunderous applause."



Kovalenok is photographed just outside the Salyut 6 hatch by fellow cosmonaut Ivanchenkov. Note the reflection of Ivanchenkov in Kovalenok's visor.

Observations from southern England some hours after the operation confirmed a wide separation of station and KRT-10 dish.

The next day was Ryumin's birhtday and he received congratulations all day from the control centre. He was congratulated on the "fine piece of work" he had done the previous day which ensured the continuity of work on the Salyut 6 space station.

The world's first unscheduled EVA had lasted for 1 hour 23 minutes.

Salyut 6 : Two More Crews

Valeri Ryumin found himself back on Salyut 6 in 1980, replacing the prime flight engineer of Soyuz 35, Valentin Legedev, who had injured himself. There were no further EVAs during this busy 185-day flight.

In 1981 Salyut 6 was again manned. Vladimir Kovalenok and Viktor Savinykh made a 75-day spaceflight during which they played host to two international crews. There were no EVAs on this flight which saw an end to Salyut 6's manned operation. This was the last time a resident crew manned a Salyut station without being scheduled to conduct an EVA.

First Outside Salyut 7 : July 30, 1982

Four years and one day after Kovalenok and Ivanchenkov had made their EVA to collect samples from Salyut 6's exterior, the first resident crew to Salyut 7 made a similar EVA, also involving some technical tests.

Anatoli Berezovoi and Valentin Lebedev boarded the new station in May 1982. Salyut 7 was designed with EVA in mind. Essentially a duplicate of Salyut 6, it did feature provision for spacewalking cosmonauts to attach extra solar power panels to the edges of the main array of three solar panels.

The task for the first crew on their EVA was, however, less demanding. In his diary of the flight Valentin Lebedev gave details about his attitude and activities before and during the EVA, which was scheduled for July 30.

On July 26 he described talking to Valeri Ryumin and asking for permission to traverse the length of the station (Ryumin was the only cosmonaut to have done this to date on Salyut 6.) Ryumin said that it was necessary to check the improved spacesuits as there was no sense in taking chances. The preparations for the walk were taking up so much time that there was not even time to gaze out of the window.

On July 27 Lebedev tried out the spacesuit. "As I started to wriggle myself into the spacesuit, I had the impression of having grown broad in the shoulders, and having too big a head for the helmet... zero gravity was of no help and I had to assist myself in with my hands to sink the legs into the suit. I took much effort, much panting and mumbling to get in," he wrote.

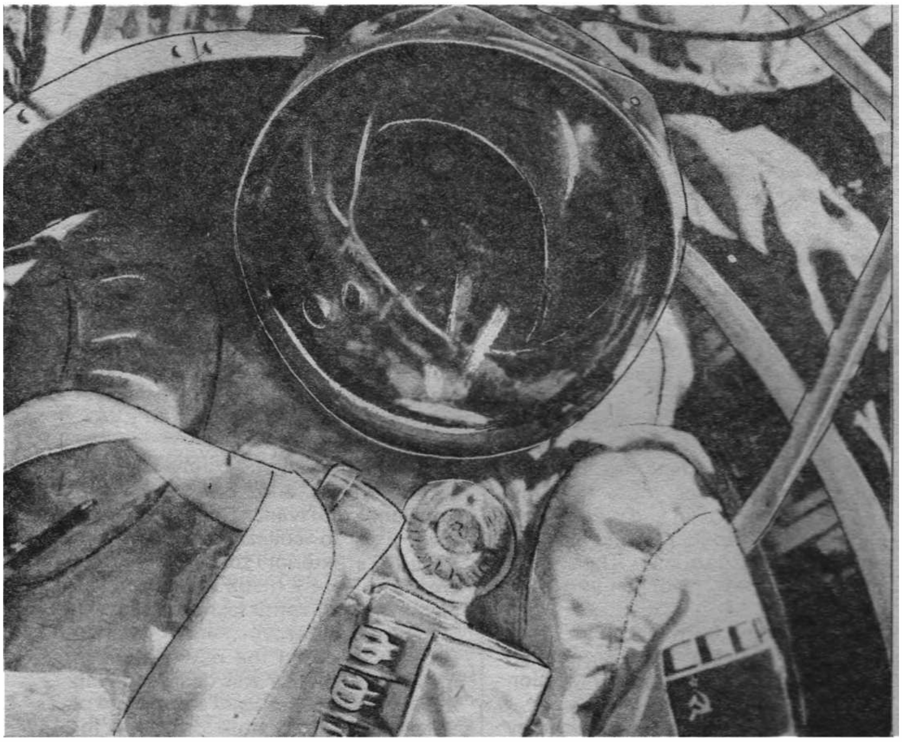
The final instructions for the EVA were radioed up on July 29. The timing was fixed to the minute and the duration was set at "more than a circuit" of Earth. Both men did not sleep well on the night before the EVA.

At 0239 GMT on July 30 the cosmonauts opened the hatch on Salyut 7's side for the first time.

ears, no pressure on you," wrote Lebedev, "the panorama was very serene and majestic."

The cosmonaut installed TV cameras and a floodlight. He made his way to the Yakor (Anchor) point near the hatch and began to collect a series of cassettes and instruments including the Medusa experiment, a panel with ampoules of the simplest organic compounds to study how life may have begun. Lebedev replaced the units with analogous ones after he had retrieved them. Other external experiments involved a cassette with 20 samples of metals under various loads of compression or tension and samples of rubber and heat-insulation materials. A micro-meteorite detector was also retrieved.

Lebedev conducted the Istok experiment involving using a special spanner on a board with nuts and bolts. The spanner featured a central rod with small spheres on the sides. It was designed to undo bolts much easier than before and also avoid the resultant metal slivers from being shaved off.



Berezovoi at the Salyut 7 EVA hatch, during his July 1982 space walk.

Lebedev said that once the hatch was opened sunlight burst in; "dust from the station flew in like little sparklets, looking like tiny snowflakes on a frosty day. Space, like a vacuum cleaner, began to suck everything out. Flying together with the dust were some little washers and nuts that had got stuck somewhere; a pencil flew by." Lebedev recalled feeling neither fear nor excitement. The huge Earth gave him a feeling of "unreality."

"Space is very beautiful. There was the dark velvet of the sky, the blue halo of the Earth and fast running lakes, rivers, fields and cloud clusters. It was dead silence all around, nothing whatsoever to indicate the velocity of the flight... No wind whistling in your

Several operations were conducted by the cosmonaut to evaluate the effective use of thermomechanical and threaded connections from different metal pairs. An assembly of pipes connected by a "memory metal" which shrinks to a pre-determined form at room temperature to form a hermetic seal was tested. The pipes joined in this manner were tested to an internal pressure of 150 atmospheres to check on their properties.

Berezovoi spent most of the EVA in Salyut's hatch passing out tools and taking TV and still pictures. At one point Lebedev complained that his feet were cold. Aleksei Leonov said this was the result of the new powerful heat extraction unit. The suit was said to be flexible and the cosmonauts were not heard to be breathing heavily.

The first EVA from Salyut 7 lasted 2 hours and 33 minutes.

In 1988 James Oberg reported that new accounts about Salyut 7 said that the Berezovoi / Lebedev EVA also saw the deployment of a synthetic aperture radar on Salyut's exterior. The 10 m long antenna was supposed to be dismantled by Kizim and Solovyov, Oberg says. However, pictures of the Salyut 7 station taken in late 1985 do not reveal any such antenna.

Soyuz T-8 : A False Start for 1983

The next resident crew to Salyut 7 were scheduled to perform at least one EVA to erect the first two sets of additional solar panels. However, after their launch on Soyuz T-8, Vladimir Titov, Gennadi Strekalov and Aleksandr Serebrov found themselves without a usable rendezvous antenna on their ship.

Despite an heroic attempt by Titov to conduct a manual approach and rendezvous to Salyut 7, docked with the large Kosmos 1443 module which contained the extra panels, the three men returned back to Earth after a two-day flight.

It is assumed that the EVA (s) would have been conducted by Titov and Strekalov.

New Solar Panels : November 1 and 3 1983

Titov and Strekalov were scheduled to be launched to Salyut 7 again on September 26, 1983 to take over the station from Vladimir Lyakhov and Aleksandr Aleksandrov who had boarded in late June to work with the heavy Kosmos.

But fate was to intervene again. Titov and Strekalov were to perform the solar panel addition EVA, an activity that Lyakhov and Aleksandrov had not trained extensively for.

Just 90 seconds before the launch of Soyuz T-10, with Titov and Strekalov aboard, a fire broke out at the base of the rocket. Thanks to the quick reactions of two ground controllers the cosmonauts became the first live passengers to test the Soyuz Launch Escape System. The cosmonauts, in the descent cabin of their Soyuz landed 4 km from the blazing launch pad. They were shaken but uninjured.

For Lyakhov and Aleksandrov the news of the failure came after their own problems with Salyut which made world headlines. An oxidiser

leak on September 9 had almost led to the men's recall. But controllers decided that the problem could be lived with and left the crew aboard awaiting the new team.

It became clear that the team already on Salyut should go outside to erect the new set of solar panels. Two separate EVAs were scheduled - the first time that the Soviets were to conduct two EVAs during a single mission and also making Lyakhov the first Soviet to conduct two sessions of EVA.

The new panels (Soviet acronym DSB) were 5m long and 1.5m wide. They provided 50 per cent of the power of the main array when both were attached. Engineer O Tsyganokov said that up to 48 different operations were needed to winch the DSB onto the sides of the existing panel. But with contingency operations there might be as many as 189 operations. To guard against these, engineers had developed various sets of rules and procedures.

The first EVA began at 0447 GMT on November 1. Aleksandrov was first out, attaching himself to an anchor point. He later recalled that there was an interesting reversal of roles for the EVA - when Ryumin made his 1979 EVA Aleksandrov was the shift chief at the control centre, now Ryumin was in that role.

"It is so very hard to describe one's emotional state on the first space walk," Aleksandrov later said. "Aboard the station the spacesuit looks like an impressive, even cumbersome device. You don't put it on, you enter it. But outside the station you feel like you're in a tiny crib suspended at a dizzy altitude."

Aleksandrov was "stunned" by the colour scheme of space. "Through the porthole you see a limited sector, but outside the station you see all the many colours of the dawn fading here and gathering intensity there. The colours merge into one another sharply and contrast each other intensely. I don't know why but I suddenly want to carry out a small experiment - to let loose some small object and see what would happen to it. I found such an object and it floated away, shining like a small star," he said.

"We were immediately told off by the control centre for our antics," recalled Lyakhov. "These small 'stars' can upset the positioning system's work."

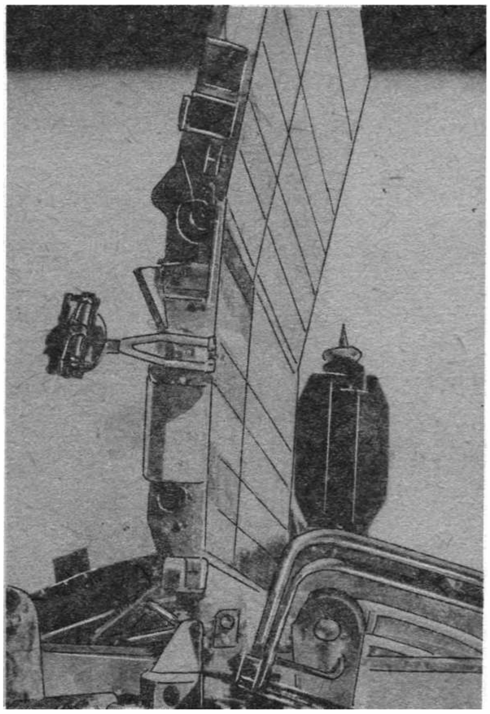
It was reported that the men took with them portable hand holds and a multipupose hand-held manipulator which made it possible to reach out the whole length of the main solar array.

Lyakhov passed a TV camera to his comrade to set up so that controllers could view the working area. The camera was mounted on a movable hinge. The two men carried a metal container to the area of the station's central solar panel. The folded DSB was removed from the container.

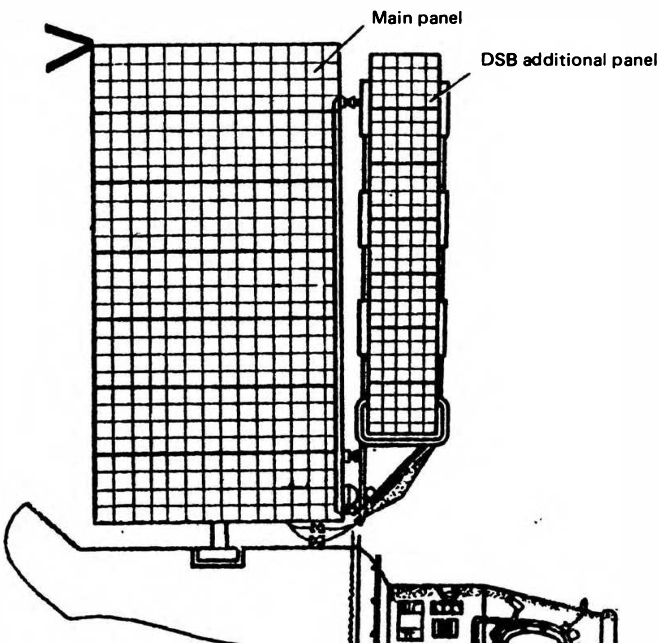
A full scale replica of a main and auxiliary solar panel was positioned in front of the desks in the control room at FRC.

By the time the men had reached the site of the work the EVA was already 40 minutes old.

There followed a series of exchanges between the men: "... no, this big one!" ; "Oh! OK." A Soviet correspondent called the exchanges businesslike. The cosmonauts were still engaged in their preparations as radio communications were lost as the station drifted out of the range of the Soviet ground tracking stations.



Salyut 7's solar panel before the addition of extra panels.



Salyut 7

Almost 50 minutes passed before contact was reestablished with FCC. Much of that time was spend in darkness. As Salyut began its passage through the daylight portion of the orbit, Aleksandrov began to winch the DSB up.

The cable to connect the DSB to the main panel was then attached, establishing the electrical connection. The work was described as being "complicated and laborious."

With the successful completion of the work the two men returned into the station after an EVA lasting 2 hours 49 minutes and 12 seconds.

In a post-EVA medical debriefing with Dr AD Yegorov, Alexandrov said that his only sensation was "of having done something well."

The second EVA began at 0347 GMT on November 3 and proceeded in a similar manner to the first. Aleksandrov reached the panel after 46 minutes. The Soviets said that two cosmonauts were duplicating the work in the tank at Star Town, a western source identified them as Leonid Kizim and Vladimir Solovyov.

The solar panel's second DSB was erected successfully and the cosmonauts returned to the station after 2 hours and 55 minutes. The Soviet coverage of the second EVA was very low-key. The work was linked to future large-scale assembly work which is to be performed during future missions.

This major feature on Soviet EVA operations continues in the next edition of *Spaceflight*.

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-4
(спейсфлайт)
По подписке 1989 г.
April 1989 US$3.25 £1.25

Spaceflight

The International M... ...utics

Vol.31 No.4

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DISTRIBUTION DETAILS

Spaceflight may be received world-wide by mail through membership of the British Interplanetary Society. Details from the above address. Library subscription details are also available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by Magnum Distribution Ltd., Cloister Court, 22–26 Farringdon Lane, London EC1R 3AU. Tel: 01–253 3135.

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Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published monthly by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L., Ltd., Aylesbury, Buckinghamshire, England.

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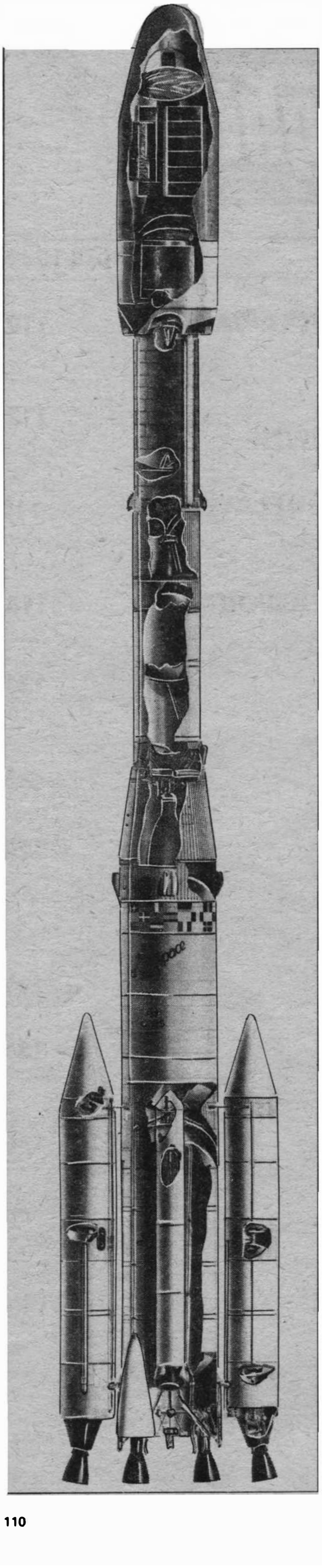
Spaceflight

The International Magazine of Space and Astronautics

Vol. 31 No. 4 April 1989

Front Cover: A dramatic view of Atlantis blasting off on Mission STS-27. This month she will make her fourth flight and deploy the Magellan probe.
NASA



Record Order Follows Ariane Success Run

Arianespace has signed a contract with Aerospatiale, MBB, SEP and Matra for the construction of 50 Ariane 4 launchers, the world's largest launch vehicle production order. The contract follows a run of ten successful launches, orbiting 17 satellites.

The agreement was signed by representatives of Arianespace and the four manufacturing companies in Evry, France on February 15. The 50 launch vehicles are in addition to the 21 originally ordered.

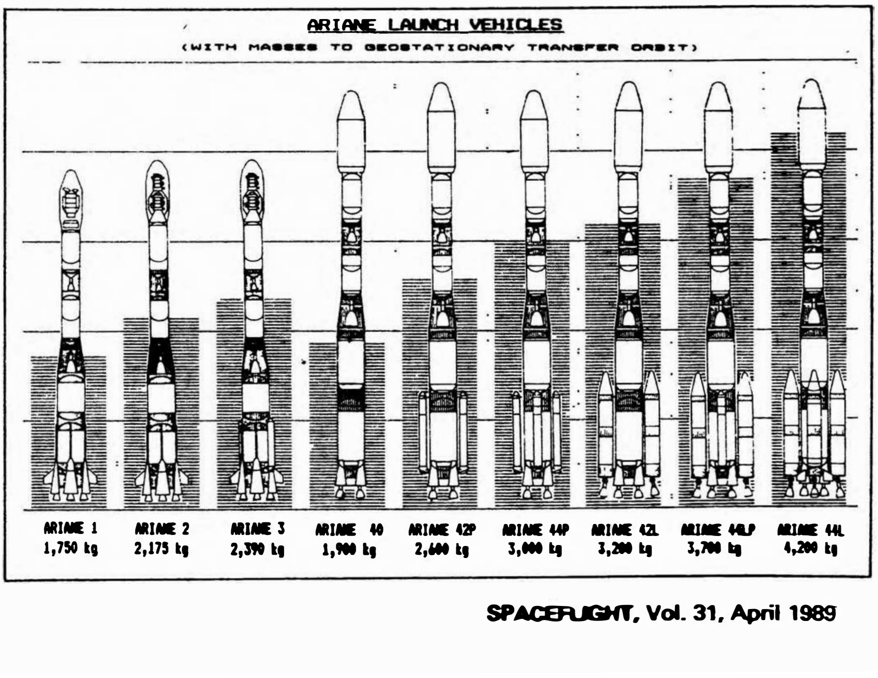
Since the resumption of flights in September 1987, following a series of failures, there have been 11 successful Ariane launches, placing 19 satellites into orbit. With its confidence restored, Arianespace placed the $3 billion Ariane 4 bulk order. The contract will lead to reduced production costs, which, according to Arianespace, will make the European launcher more competitive in the growing commercial market. Arianespace's Chairman, Frederic d'Allest, was in optimistic mood after signing the agreement, he said, "This contract emphasizes the industrial scope of the Ariane programme and strengthens Arianespace's position in an increasingly competitive environment". D'Allest has recently resigned from his position as head of the French space agency, CNES, to devote his full attention to marketing the Ariane launcher.

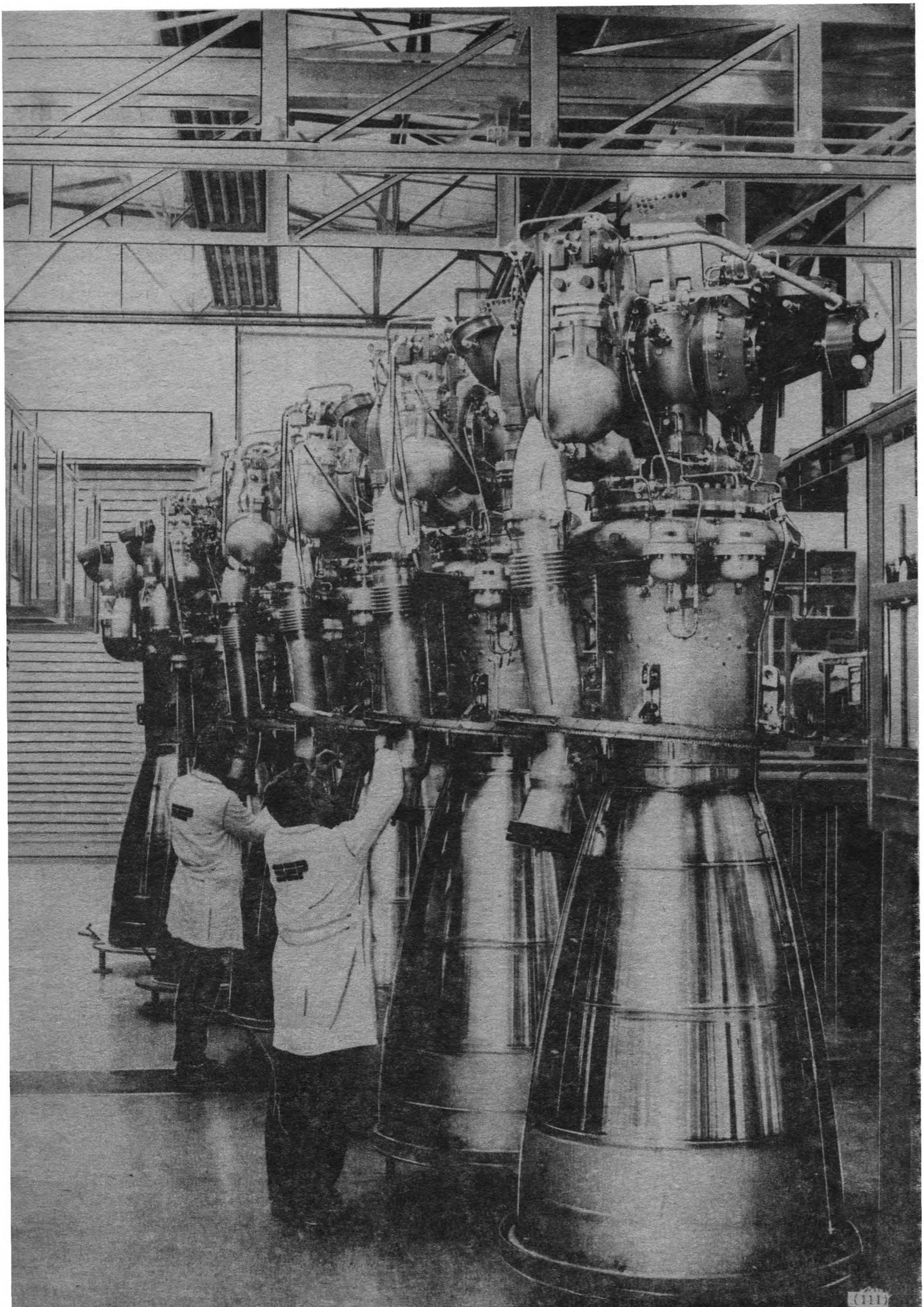
Under the agreement Aerospatiale is to provide 50 first and third stages and 60 strap-on solid rocket boosters. MBB/ERNO will supply 50 second stages and 96 strap-on liquid propellant boosters. Matra will manufacture 50 vehicle equipment bays, which carry the Ariane's guidance and control systems. The Societe Europenne de Propulsion (SEP) will provide 346 Viking engines (each Ariane 4 first stage has four Viking V motors, the second stage is powered by a single Viking IV and the strap-on liquid boosters each carry one Viking VI engine). SEP will also be responsible for the construction of 50 HM7B cryogenic engines for the third stage. The construction rate of the Ariane 4 will be five to eight vehicles per year, the first is to be delivered in late 1991 and the last in 1999.

The contract will be a boost for the Ariane subcontractors in eleven European nations, including the UK's British Aerospace, which manufactures the Spelda payload structure, and Ferranti who supply the gyro platform for the Ariane's guidance systems. Arianespace believes the contract will ensure the jobs of 12,000 people employed throughout Europe in the Ariane programme.

The production line for the Viking motor used in Ariane first, second and strap-on stages. *SEP*

(Left) A cut-away of the Ariane 4 illustrates the complexity of the vehicle. Arianespace sees the booster as its 'work-horse' for the 1990s. During this period fifty launchers will be delivered to the company, which expects to take a large slice of the satellite launching market. *Arianespace*





VLADIMIR SHATALOV

An example of the new openness in the Soviet space programme was displayed recently. The Soviet newspaper *Trud* gave its readers the opportunity to put questions to Vladimir Shatalov ex-cosmonaut and Chief of the Cosmonaut Training Centre.

A. Rodionov, Leningrad: Following Buran's brilliant debut, has the question of the second flight been decided? What is your personal opinion — should it be manned or unmanned? To put the question more broadly: Why do we trust automatic machines more than man on space flights, and why do we endeavour to allocate him a secondary role?

Shatalov: I will begin by answering the last question. This is a rather old discussion: who should have priority on a space flight — man or an automatic machine. A person has his functions, while machines have theirs. Today it is impossible to imagine a space flight without modern high-speed computers and all the very complex technology. But it is still the cosmonaut who is master aboard the craft. He is not a 'passive observer' — it is the pilot and researcher who resolve the complex problems which frequently arise on a flight.

In the past there was a clash of two positions, two approaches to manned flights. Certain designers stubbornly believed that technology must be trusted more than people. A serious blow was dealt to these views back in 1965 at the time of Voskhod-2. The craft was unable to return to Earth from the orbit because of faults in the automatic equipment. It was only by using the manual control system that the crew guided the craft onto the descent path.

Later too, cosmonauts repeatedly found a way out in very complex critical situations. Recall, for example, how in June 1985 Vladimir Dzhanibekov and Viktor Savinykh approached in the manual mode the uncontrolled and unoriented Salyut-7 station, flew around it, executed a meticulously precise and very complex docking manoeuvre and repaired the systems which had gone out of commission.

As for Buran's next flight, I believe that it could be a manned one, after comprehensive training of course. However, there are, of course, other opinions. As far as I know, the final decision has not yet been made. First we have to conduct a careful investigation of the craft which has returned from space.

V. Timofeyev, Voronezh: How many crew members will there be on Buran's first manned flight? What is the largest possible crew on board a shuttle? Who is training to fly on Buran?

Shatalov: Two cosmonauts will conduct test flights on Buran before it becomes operational. Subsequently, there could be four people manning Buran. And for individual tasks requiring the participation of different kinds of researchers, as many as 10 people could fly aboard Buran.

The cabin is divided into two compartments — upper and lower. The total volume is 73 cu.m. (more than seven times that of the three-seater Soyuz-TM).

Now, about those who are being trained to fly in Buran. They are experienced test pilots — I. Volk (group leader), V. Zabloltskiy, R. Stankevicius, U. Sultanov, M. Tolboyev, S. Tresvyatskiy and Yu. Sheffer.

K. Khasanov, Oktyabrskiy, Bashkir ASSR: The newspapers have written that reserve landing strips will be constructed for Buran-type shuttles. Where precisely? Will Buran be our only vehicle, or is it planned to build other shuttles?

Shatalov: One reserve landing strip for shuttles will be completed in the region of Simferopol, and another in the east of the country. Of course, the present Buran will not be our only space shuttle. A second craft is now being assembled in the Baikonur Cosmodrome's assembly and testing block.

D. Shumilin, Minsk: How many flights can a shuttle make? How long can it stay in orbit?

Shatalov: The shuttle is designed for 100 space flights. Its stay in orbit depends on the mission. At the first stage — up to seven days; subsequently — up to one month.

T. Grishchenko, Kiev: What is the fate of the Salyut-7 orbiting station?

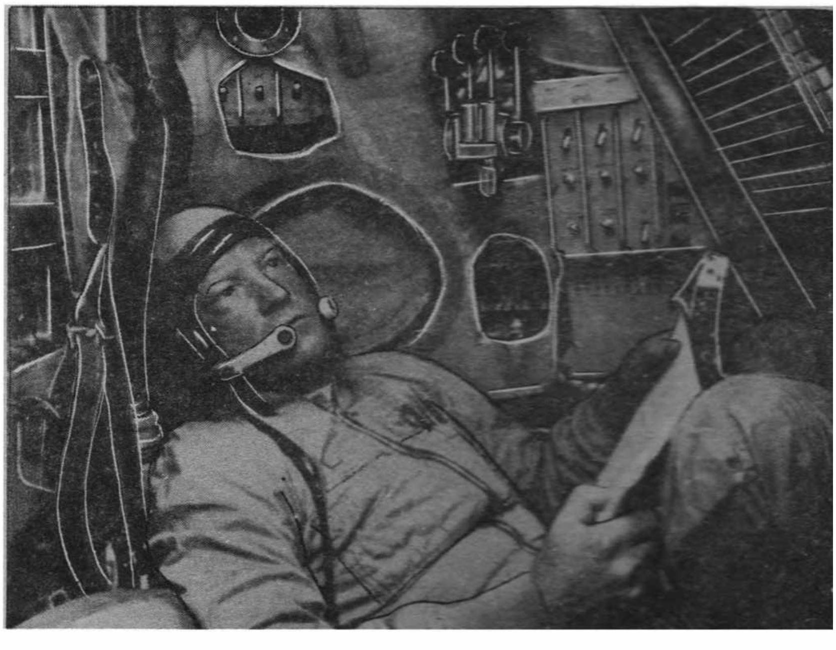
Shatalov: It has been decided to leave this station in space in order to conduct service life tests. This is important to designers for Mir has largely been manufactured from the same materials as Salyut-7. Therefore, it would be interesting to learn how long these materials retain their properties and how they change under the impact of cosmic rays, meteorites, the vacuum and the tremendous temperature gradient. We have to check the thermal and meteorite protection and so forth. After the service life tests have been completed, Salyut-7 will either be returned to Earth by Buran or sunk in the ocean after descending from orbit.

This question was the subject of 67 letters to *Trud*: Is it not time to cut appropriations for space exploration?

Shatalov: Space exploration is of tremendous significance for the development of science and economic progress is impossible without it.

Let's see what space exploration gives us directly for the practical needs of the Soviet economy.

Igor Volk, group leader of the Soviet shuttle cosmonaut corp. Volk is expected to command the first manned flight of Buran. *Novosti*



First, the satellite communications system. Television broadcasting and multichannel long-distance telephone and telegraph communications embrace practically the entire population of the USSR (93%). By the year 2000, seven out of every ten messages carried by all communications channels will be transmitted via space. But if we were to lay down cable the cost would be fantastic.

There is the Tsikada satellite navigation system, which serves ships in the World's oceans. Weather satellites — the use of meteorological information from space ensures an annual saving of up to 500-700 million roubles.

And then such a very important area as study of the Earth's natural environment and resources. Photographs from space combined with aerial and traditional geological exploration methods and with geophysical and geochemical research make it possible more quickly and more cheaply to determine promising areas to look for minerals. For example, a comprehensive analysis of data from an investigation of the Kola peninsula, the Verkhoyansk range and the region around the Sea of Okhotsk revealed a number of promising areas to prospect for ore deposits. Judge for yourselves: what is more profitable — to extract our own metal or purchase it from abroad?

We have begun looking for minerals in remote desert regions: rare metals in the Far East, copper in the region of the Baykal-Amur mainline railway and tin in Yakutia. The Astrakahn oil and gas bearing region was selected for priority development. The prognosis was brilliantly confirmed.

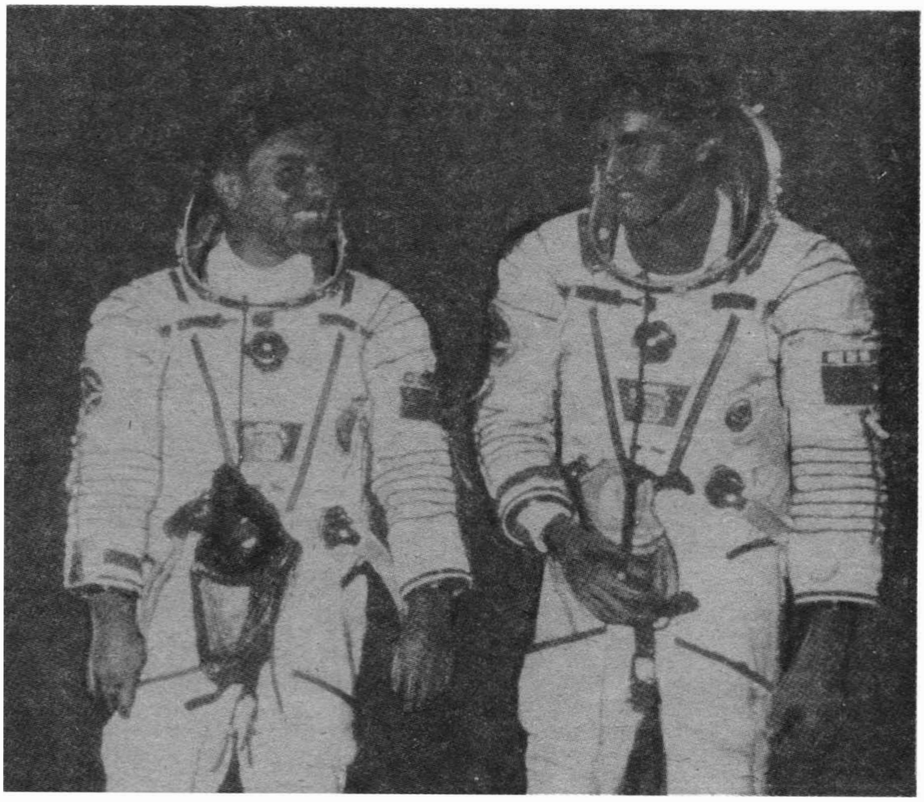
As we see, there is considerable practical return on space research. But I must say that those readers are right to put this question: Why is such insignificant use made of space flights to resolve urgent national economic tasks?

To speak of manned flights, for example, the return on them for our economy could, in my view, be immeasurably greater. It was proved long ago that under weightless conditions in orbit it is possible to obtain invaluable medical preparations and unique crystalline materials, to carry out manufacturing processes that cannot be achieved on Earth.

Experiments have been finalised, but what now? On a permanently manned orbiting station it would be possible to organise semi-industrial production of medicines, crystals, semiconductors and many other things. The technical possibility for this already exists. But for some reason no one is interested in it. Perhaps we have not yet woken up after the 'stagnation hibernation'? Industrial firms in the West are fighting vigorously to buy space aboard the US shuttle, a fight for every gram of payload stowed aboard the craft. Their aim is to open up space for industry as quickly as possible. Unfortunately, such an attitude is very rare in our country. We have a big shortfall here.

D. Bortsov, Novosibirsk: What is the programme of manned flights in 1989?

Shatalov: A Volkov, S. Krikalev and V. Polyakov are currently on duty aboard the Mir. They will be relieved by another crew in April. Volkov, Krikalev and Polyakov will return to Earth on April 29th. The new crew will work until the autumn, when there will be another change of watch.



Aleksandr Volkov (left) and Sergei Krikalev will return to Earth on April 29. *CNES*

S. Markina, Yaroslavl: Are long flights necessary — lasting one year, for example?

Shatalov: If we seriously want to open up space, we cannot do without such flights.

A number of specialists consider work by space crews lasting one year to be the optimum. Others, however, are convinced that crews work most efficiently for four to six months. If we disregard superlong flights designed to study the effect of weightlessness and other space factors on the human organism then orbital flights lasting no more than six months, with the possibility of a 'shift overlap', should in my view be the norm.

I believe it to be expedient to change crews, not over the space of a few days, but over a longer period. It is a matter of having both crews work together for a month or two and carry out the most difficult, intensive programme during this period. During the remaining three or four months the one crew should tackle research, manufacturing processes, the unloading of Progresses and so forth. Thus two or three missions could be carried out over the period of one year. Foreign cosmonauts could work on the station during those few months when two crews will be working simultaneously on the orbiting complex.

S. Grachev, Kursk: The newspapers have written that specialised modules will be dispatched to the Mir complex. When will this happen?

Shatalov: It is planned to launch two modules and dock them with the complex this year. The designers want the interval between the docking of the first and the second modules to be minimal. For an asymmetry will arise in the space complex when one of them docks — which will complicate control of the station.

D. Krutoyarov, Tomsk: Ground services — controllers, designers — have recently been making rather a lot of mistakes. One of the two automatic interplanetary interplanetary stations now flying towards Mars went out of commission because of an incorrect command. There were two malfunctions in a row when international crews returned last September and December — the landings had to be postponed. What accounts for this?

Shatalov: The growing complexity of space programmes demands special composure, attentiveness and responsibility on the part of all involved in a space flight, of cosmonauts, designers, scientists and ground control services. Unfortunately, no one is insured against mistakes. Thus, what is needed are systems which will provide, for example, back-up insurance and additional verification of the correctness of commands transmitted to space from Earth.

The growing breadth and complexity of space programmes, including the organisation at the mission control centre of parallel work with other space objects

SOVIET SCENE

The patch for the joint Soviet-French mission. Shatalov says talks are underway with Britain and Malaysia for similar international flights. *CNES*

(Buran and Phobos, for example), requires the involvement of a large number of young specialists in flight control. Maybe they have not all been trained adequately for such work. At the cosmonaut training centre every specialist who deals with the crews must receive the same training as the cosmonauts themselves. Only then can he be considered a real specialist.

V. Shurgot, Moscow: What international flights are planned in the future?

Shatalov: An accord has been reached on a Soviet-Austrian space flight.

In an interview in the newspaper 'Express' the FRG Minister of Research and Technology expressed the hope that the first joint Soviet-West German space flight would take place no later than 1991.

Talks are being held with Britain and Malaysia. The USSR Chief Directorate for the Development and Use of Space Technology for the National Economy and Scientific Research is ready to receive applications from any country to participate in flights on a commercial basis.

The French side wants month-long joint Soviet-French flights to be made once every two years. This has greatly heartened Michel Tognini, the back-up for Jean-Loup Chretien, who recently returned from space. Tognini now has a real chance of going to an orbiting station in 1990 or early 1991.

V. Molchanov, Tula (A *Spaceflight* reader in the USSR): I am very interested in cosmonautics. I was told that a women's crew — S. Ye. Savitskaya, Ye. A. Ivanova and Ye. I. Dobrokvashina — had been training to fly to an orbiting station. Nothing was reported about this. Who were their back-ups?

Shatalov: Yes, in 1984 it was decided to prepare a women's crew to fly to the Salyut-7 orbiting station. The commander was to be Savitskaya, who had already made a space flight in July of that year. The crew also included engineer Ivanova and physician Dobrokvashina. Their back-ups were A. Viktorenko, A. Aleksandrov and V. Solovyev. Why a male crew? The answer is simple: every crew must include one cosmonaut who has already made a flight. In the women's crew this was Savitskaya. But there was no woman cosmonaut for a back-up women's crew who had experience of a flight and who was ready at that time for a new one. That is why the standbys were men. But after the birth of Savitskaya's baby the women's flight did not take place.

V. Petrovicheva, Ivanovo: Will women fly in space this year?

Shatalov: No, such a flight is not planned. Women are not currently being trained at our centre.

V. Korablev, Voronezh: Are our cosmonauts training for a Moon flight?

Shatalov: There is no such need at present. But it is impossible to imagine space exploration in the future without exploring the Moon and setting up lunar bases there.

S. Trunova, Baku: Why is nothing heard about cosmonauts A. Zaysev and A. Kaleri, who were reported earlier to be members of back-up crews? How many cosmonauts are in the detachment now?

Shatalov: Kaleri and Zaytsev are not undergoing training for medical reasons. Five crews are now preparing for future flights, and each one consists of two men: commander and flight engineer. Ten people in all. Depending on the future intensified flight programme researchers who are being trained in their own programmes may later be included in the crews. The group which is training to fly the shuttle also has a special programme (based on flight tests).

T. Spiridonov. Arkhangelsk: Are V Savinykhm, G. Grechko, A. Yeliseyev, V. Askenov and V. Bykovskiy training for new flights?

Shatalov: No, they are not. Savinykh is now Rector of the Moscow Institute of Engineers of Geodesy, Aerial Surveying and Cartography. Grechko is working in an institute of the USSR Academy of Sciences. Yeliseyev is Rector of the N.E. Bauman Moscow Higher Technical School. Askenov is director of a scientific research institute. Bykovskiy is Director of the House of Soviet Science and Culture in Berlin (GDR).

S. Orlov, Sudjarvi: I still remember with anguish the tragic demise of the first Soviet crew of an orbiting station — G. Dobrovolskiy, V. Volkov and V. Patsayev. Everything connected with that flight is dear to history. Would it not be possible to name the cosmonauts who were in the back-up crew?

Shatalov: The thing is that Dobrovolskiy, Volkov and Patsayev were members not of the first but of the second crew for the Soyuz-11 and Salyut orbital station flight. The first crew consisted of A.A. Leonov, V.N. Kubasov and P.I. Kolodin (he now works at mission control centre). But when there were just a few days to go to the launching of Soyuz-11, physicians at Baikonur grounded Kubasov. If one crew member is taken off a flight, this means that the entire crew cannot fly. The state commission made the decision: the second crew — Dobrovolskiy, Volkov and Patsayev — would go into space.

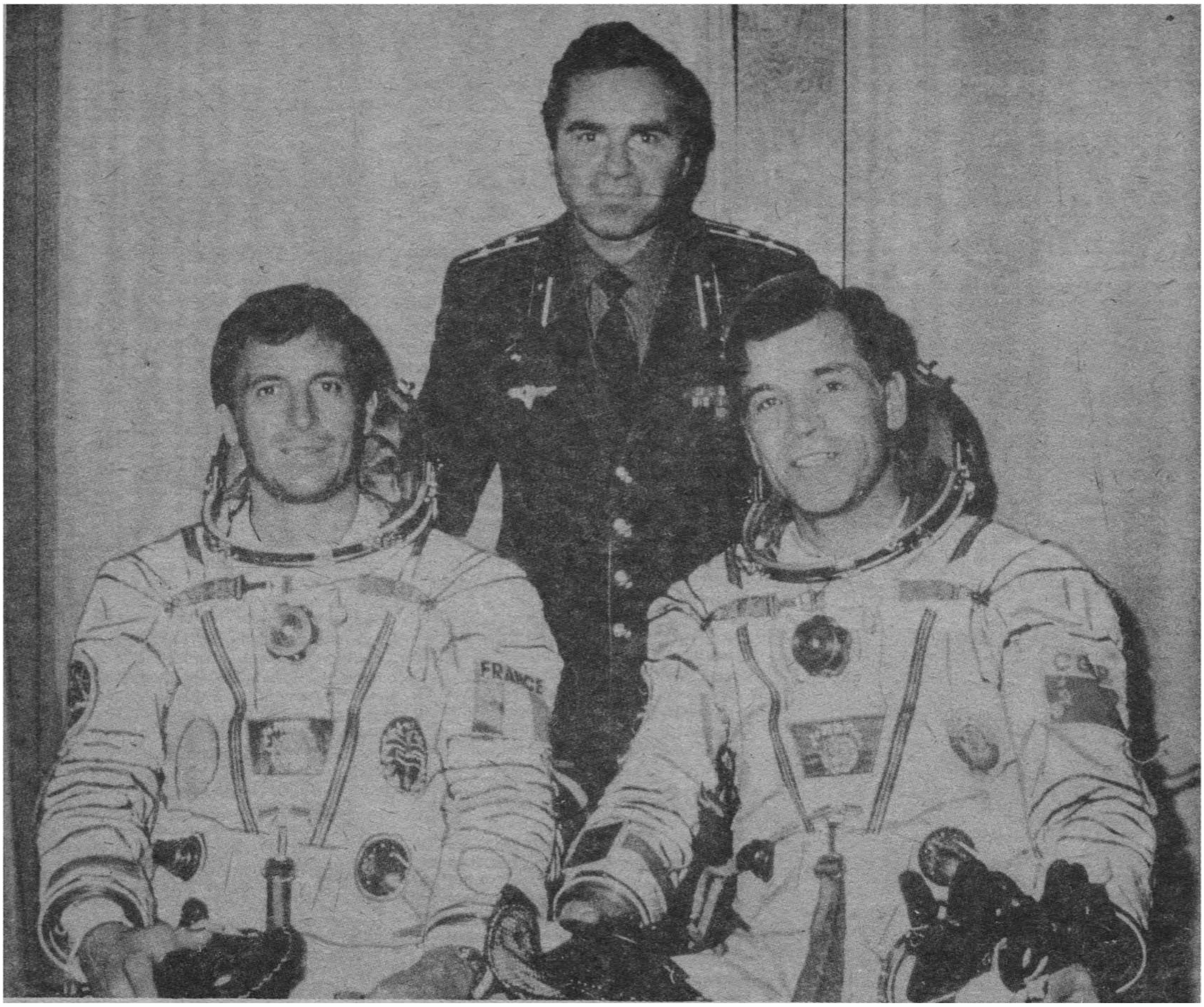
I remember how upset Leonov, Kubasov and Kolodin were at being taken off the flight. But a truly dreadful blow still awaited us when our comrades died during their return to Earth. Everyone took it unbearably hard at the time. It was impossible to look at Kubrasov, Leonov and Kolodin with their darkened, pinched-looking faces, feeling deeply the death of the cosmonauts with whom they had flight trained and who had taken their places.

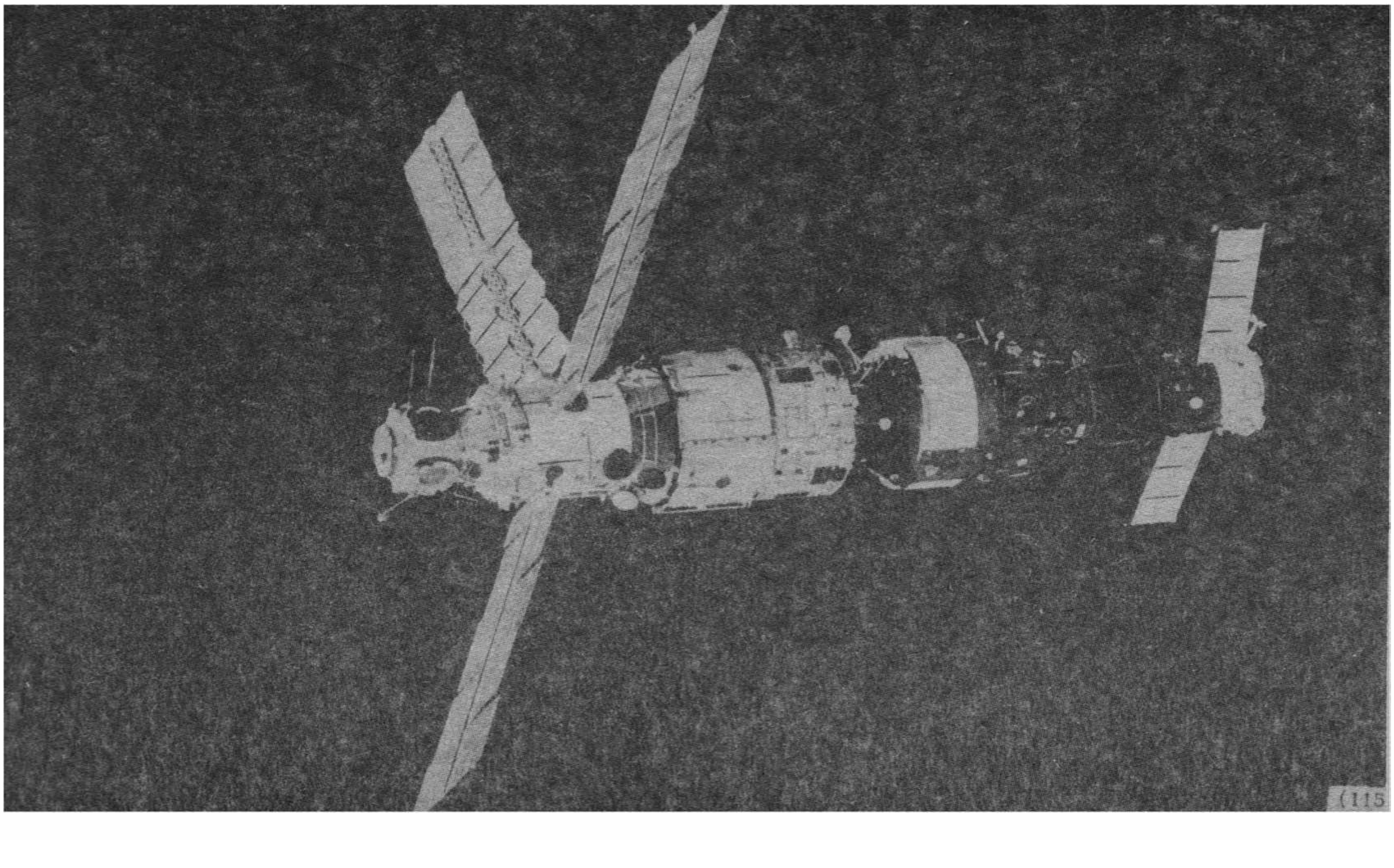
V. Trofimov, Chelyabinsk: How do you see the future of cosmonautics?

Shatalov: The industrialisation of space. Plants in orbit which will give people materials and medicines that are inaccessible on Earth. Satellite information systems. High-capacity orbiting power stations.

I am also sure that there will be lunar settlements (with the aim of producing many rare materials from lunar rock for terrestrial needs and for lunar bases) and interplanetary expeditions.

TOP: The back-up crew for the Joint Soviet-French mission (left to right) Michel, Tognini, Aleksandr Viktorenko and Aleksandr Serebrov. BOTTOM: The Mir space station in orbit, seen from an approaching Soyuz spacecraft. *CNES*

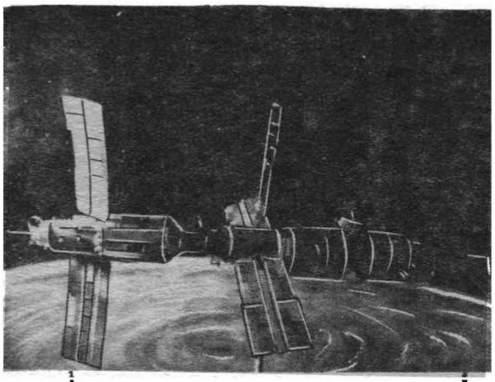

FRANCE

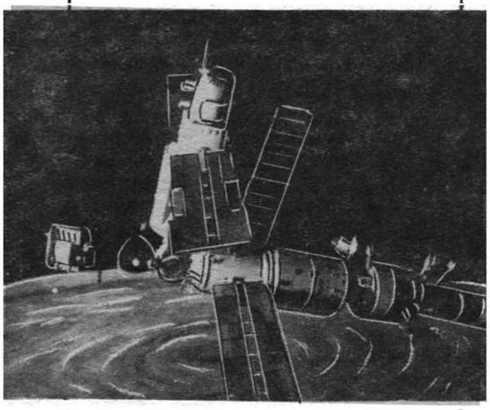


SOVIET SCENE

Mir Expansion Delayed

The Soviet space agency, Glavkosmos, has provided *Spaceflight* with up-to-date, accurate information and diagrams of Soviet spacecraft. The material includes information on the first Mir module, the launch of which has been delayed from April to later this year. Regular *Spaceflight* correspondent, *Neville Kidger*, outlines the changes made to the Soviet plans.





Models by *Phil Mills* illustrate the docking procedure for the first Mir module. The module first docks with Mir's front axial port (top) and is then transferred by a remote manipulator arm on the module to the radial port (bottom). The module is expected to dock with Mir later this year.

By Neville Kidger

The Mir space station is currently manned by Aleksandr Volkov, Sergei Krikalev and Dr. Valeri Polyakov. Under the original flight plan Volkov and Krikalev were to conduct two EVAs to install additional solar sensors to Mir's exterior to aid the orientation of the complex.

At the end of April the complex was to receive a 're-equipment' module, which would feature a section for EVAs with a 1 metre diameter exit hatch at the front. It was also to contain a multi-spectral camera system made in East Germany, and a life science experiment featuring small Japanese canaries.

The crew was to have been relieved on the complex by cosmonauts Aleksandr Viktorenko and Aleksandr Serebrov. The latter of these two was to have conducted an EVA from the new module with the brand new Soviet Manned Manoeuvring Unit (MMU), which was shown to Western visitors at Baikonur in November 1988.

Soon after the launch of the 're-equipment' module, a second module was to have been docked with Mir so that the complex did not become asymmetric. With a single module attached to Mir the complex would become difficult to manoeuvre, expending much fuel.

However on February 21 chief spacecraft designer, Yuri Semenov, told Soviet TV viewers that the first module would now be launched in the second half of 1989. The MMU test would take place after this.

The second large module would be a technological one. This is to be a mini-factory for growing crystals in weightless conditions. These are intended for enterprises in the USSR making electronics and lasers. The space-grown crystals will make possible the creation of new super-fast integrated circuits Semenov said

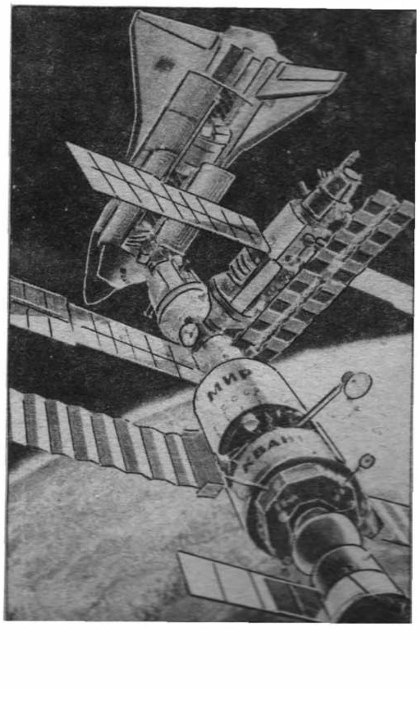
The module will also carry a special unit for work in biotechnology and will produce up to 100 kg of products per year after it begins operations in late 1990 or early 1991.

Semenov said that ecological monitoring equipment, being developed at the moment, would be placed on the module This possibly accounts for the delay of the first module which Volkov's crew was expecting. The task of launching the modules is complex because they have to be prepared simultaneously — a problem with one would ground the other.

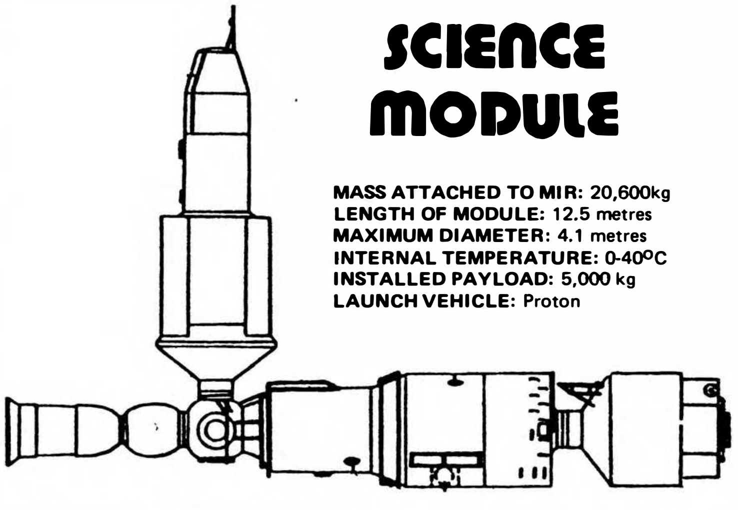
The result of the delay is a major change to the Volkov crew's mission. The EVAs have reportedly been cancelled and the replacement crew, due to be launched on April 19, although still headed by Viktorenko may not contain Serebov, who trained extensively for the MMU spacewalk. The Volkov mission ends on April 29. Polyakov may remain onboard to continue his work with the new crew, which will return after a six month period in orbit.

The next instalment of ***Spaceflight's*** regular Mir Mission Report will contain full details on the flight of Volkov, Krikalev and Polyakov.

A Soviet painting of Buran docked to the Mir space station. *Soviet Union*



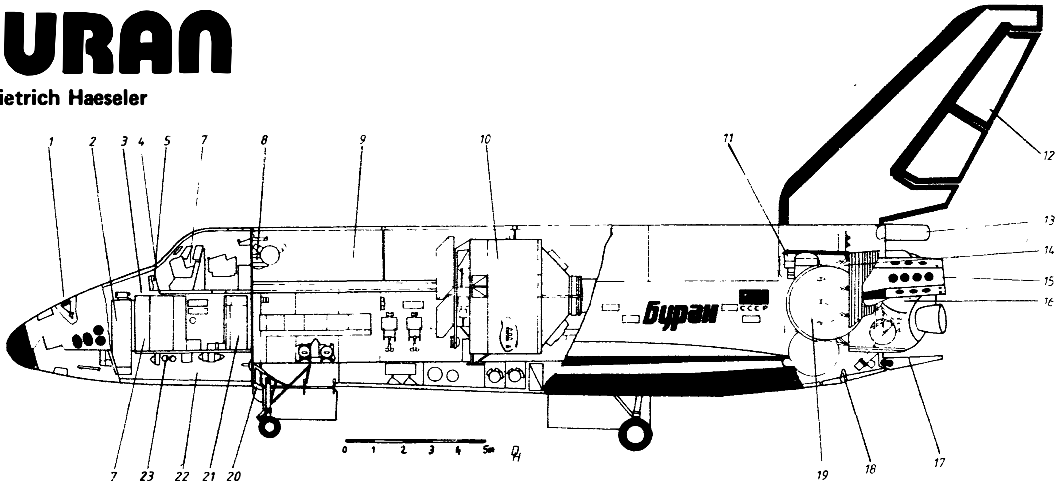
SCIENCE MODULE



MASS ATTACHED TO MIR: 20,600kg
LENGTH OF MODULE: 12.5 metres
MAXIMUM DIAMETER: 4.1 metres
INTERNAL TEMPERATURE: 0-40°C
INSTALLED PAYLOAD: 5,000 kg
LAUNCH VEHICLE: Proton

BURAN

By Dietrich Haeseler

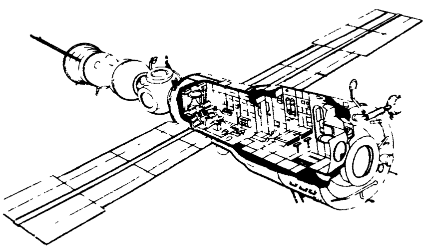


1. Forward reaction control thruster block
2. Equipment bay 1
3. Habitable module
4. Cabin
5. Equipment bay 6
6. Equipment bay 7 and 7A
7. Flight deck
8. Module with command equipment
9. Payload bay
10. Block of additional equipment (space station module)
11. Auxiliary power unit
12. Vertical stabilizer with airbrake
13. Braking parachutes
14. Basis block of the unified propulsion system
15. Reaction control thruster block
16. Fuel tank (kerosine)
17. Body flap
18. Lower central stage attachment point
19. Oxidizer tank (liquid oxygen)
20. Upper central stage attachment point
21. Equipment bay 2
22. Instrument section
23. Temperature regulation system

( ): Denotes authors additions.

Source: Soviet Union 1/89. p.10-13

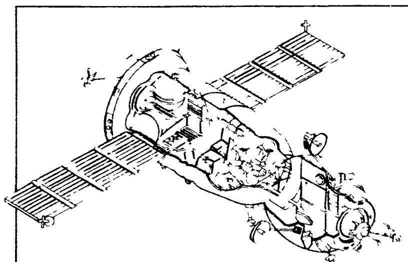
MIR



MASS OF BASE BLOCK: about 21,000 kg
LENGTH OF BASE BLOCK: 13.13 metres
LENGTH OF WORKING COMPARTMENT (WC): 7.67 metres
MAXIMUM DIAMETER OF WC: 4.2 metres
DIAMETER OF TRANSFER COMPARTMENT (TC): 2.2 metres
LENGTH OF TC: 2.84 metres
ORBIT: 300 to 400 km
INCLINATION: 51.6°
ORBITAL PERIOD: 90.3 to 93.4 minutes
PRECISION OF ORIENTATION:
 – **COARSE MODE:** not less than 1.5°
 – **FINE MODE:** not less than 15'

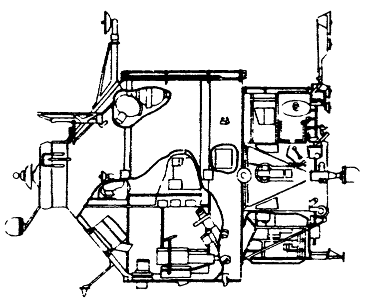
ATMOSPHERE:
 – **PRESSURE:** 800 to 970 mm mercury
 – **COMPOSITION:** as Earth atmosphere
TOTAL LENGTH OF COMPLEX (SOYUZ-MIR-KVANT-PROGRESS: 32.9 metres
MAXIMUM WIDTH ACROSS SOLAR PANELS: 29.7 metres
NUMBER OF MODULES: 5
NUMBER OF CREW:
 – **RESIDENT CREW:** 2 to 3 people
 – **VISITING CREW:** 2 to 3 people

Mir, Kvant, Soyuz, Progress and Science Module data and diagrams courtesy of Glavkosmos.



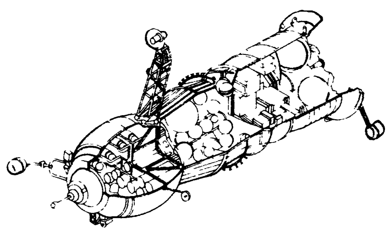
SOYUZ TM

SPACECRAFT MASS: 7,070 kg
LANDING CABIN MASS: 3,000kg
LENGTH OF SPACECRAFT: 6.98 metres (minus docking probe)
MAXIMUM DIAMETER: 2.72 metres
WIDTH OF SOLAR PANELS: 10.6 metres
CREW: up to three people
FLIGHT TIMES:
 - **AUTONOMOUS:** up to 3.2 days
 - **ATTACHED TO MIR:** up to 180 days



KVANT

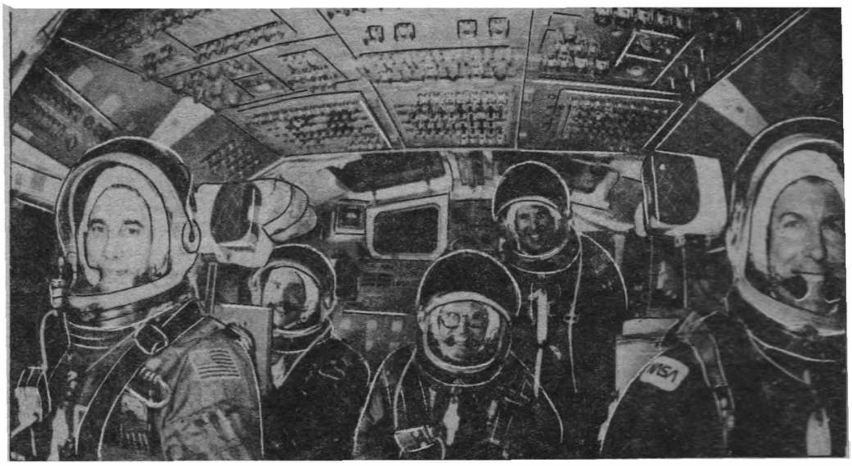
MASS ATTACHED TO MIR: 11,000 kg
LENGTH OF MODULE: 5.8 metres
MAXIMUM DIAMETER: 4.15 metres
VOLUME OF PRESSURISED COMPARTMENT: 40 cubic metres
PAYLOAD MASS: 4.1 tonnes



PROGRESS

SPACECRAFT MASS: 7,240 kg
CARGO CAPACITY: up to 2,400kg
DRY CARGOES: up to 1,400 kg
FUEL: up to 1,200 kg
LENGTH OF SPACECRAFT: 6.98 metres (minus docking probe)
FLIGHT TIMES:
 – **AUTONOMOUS:** up to 3 days
 –**ATTACHED TO MIR:** up to 90 days

Shuttle Fleet Status



The STS-29 crew during pre-flight training. (left to right) Pilot John Blaha, Mission Specialists Jim Bagian, Jim Buchli and Bob Springer, and Commander Michael coats. *NASA*

With seven shuttle flights planned for 1989, the shuttle processing facilities at the Kennedy Space Center (KSC) are a hive of activity. *Spaceflight* continues its regular Shuttle Fleet Status report, bringing readers up to date with the very latest news from the Cape.

Discovery OV-103 STS-29

At the time of going to press there was a race against time to launch Discovery on mission STS-29. The mission was scheduled for March 11, but delayed until March 13, when Discovery's Master Event Controller failed. Columbia's controller was removed and installed in Discovery on March 7.

Replacement high pressure oxidizer turbopumps were successfully installed in Discovery's engines out on the launch pad. The pumps were delivered and fitted earlier than expected and the work was completed on February 22.

If Discovery's launch slips beyond March 18 the mission would have to be postponed so Atlantis can meet the April 28-May 27 launch window for Magellan. A postponement could prompt a major reorganisation of the shuttle schedule. Discovery is to launch the third Tracking and Data Relay Satellite (TDRS), a vital communications link for the Hubble Space Telescope, which is due for launch in December. ***Spaceflight*** will provide a full report on the outcome of the mission next month.

During the preparations for STS-29, Discovery was modified to carry the Galileo Jupiter probe and the Ulysses solar polar orbiter. Both require additional cooling equipment whilst in the payload bay. Atlantis has already undergone the necessary modifications and is scheduled to launch both probes. By converting two orbiters NASA can switch the payloads if Atlantis is unable to make the flight.

Atlantis OV-104 STS-30

Atlantis has to meet the vital 30 day launch window for the Magellan probe. Stacking of the Solid Rocket Boosters for STS-30 was completed on February 17, the External Tank was attached several days later. Atlantis was scheduled to be rolled over from the Orbiter Processing Facility (OPF) to the Vehicle Assembly Building (VAB) on March 9 and mated the SRB/ET stack later that day. While in the VAB work will begin on changing Atlantis' oxidizer turbopumps in the same manner as Discovery. Depending on the STS-29 launch date, the pump replacement could be completed at the launch pad.

Atlantis' tires were installed over the weekend of February 18/19, as were the crew seats. A new location for the seats will allow more room and greater reach for the crew while in their launch and re-entry partial pressure suits.

Meanwhile work on Magellan continued, the probe was mated to its IUS booster and will be moved to the launch pad about a week after the launch of Discovery — this will allow time for the payload facilities at the pad to be fully cleaned.

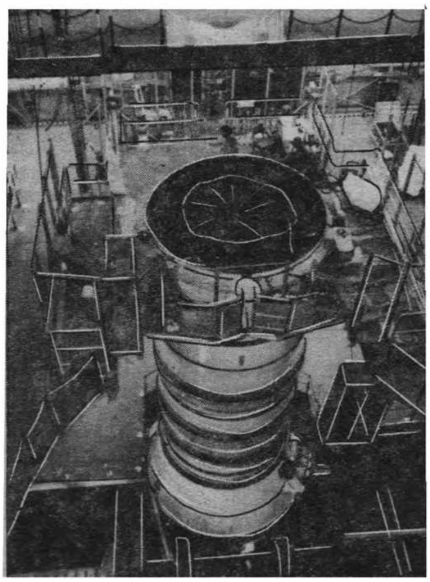
Spaceflight will carry an update on the preparations for STS-30 next month.

Columbia OV-102 STS-28

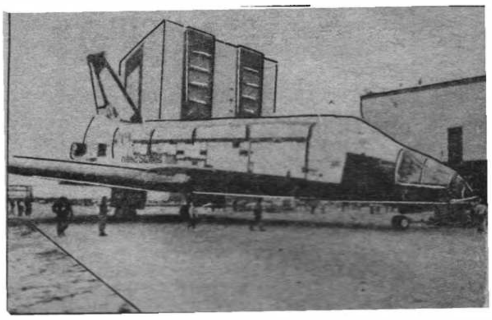
Columbia has been undergoing modifications introduced after the Challenger accident. She was transferred from the Orbiter Maintenance and Refurbishment Facility to Bay 1 of the OPF on January 23, where work accelerated to prepare her for a July launch. Much tile work remains on NASA's oldest orbiter, so much in fact, that Columbia's launch will almost certainly be delayed.

Work to assemble the SRBs for STS-28 began on February 23.

(Left) Engineers replace one of Discovery's high pressure oxidizer turbopumps, out on pad 39B at the Kennedy Space Center. (Right) Stacking of the STS-30 boosters begins in the VAB. *NASA*



Columbia, with many of her tiles missing, is towed to Bay 1 of the OPF on January 23. *NASA*



NASA-DoD Study Highlights Debris Threat

A six month joint NASA-Department of Defense (DoD) study of orbital debris has concluded that, left unchecked, the growth of debris could threaten the safe and reliable operation of manned and unmanned spacecraft in the next century.

The study reviewed current policies and activities designed to reduce the amount of space debris or mitigate its effects and explores potential opportunity for further action. International efforts, legal issues and commercial regulations were also examined.

The report cites satellite and rocket body fragmentation as the principal source of orbital debris. But it recognises that current knowledge of the orbital debris population is limited by the current observation methods.

An estimated 7,059 trackable objects are in orbit around the Earth, the report states Of that number 1,695 are active and inactive spacecraft, 1,076 are spent rocket bodies and 4,288 are fragments and other debris. The report estimates that the number of trackable objects represents only about 0.2 per cent of the orbital debris population. The estimated mass of man-made objects in various orbits is about 6.6 million pounds.

Uncertainty as to exactly how much debris is in orbit makes it difficult to assess the true risk posed to spacecraft, the report states, and that in turn creates uncertainty as to the urgency for action and the potential effectiveness of any corrective action.

NASA's Jet Propulsion Laboratory recently issued a request for proposals for a ground based radar to track orbital debris as small as 1 cm in diameter at an altitude of 500 km. The US Space Command today tracks objects only as small as 10 cm in diameter.

The report also details the effects of collisions that occur at the extremely high speeds these objects are travelling, called hypervelocity In low-Earth orbit (LEO), debris circles the globe at 7 km per second When these objects collide with each other or with operational spacecraft at a combined velocity of 10 km per second, the results can be serious or catastrophic, the report states.

For example, a 0 3 cm object travelling at 10 km a second has the destructive power of a bowling ball travelling at 60 miles per hour. Or a 1 cm aluminium sphere travelling at 10 km per second has the destructive power of a 400-pound safe travelling at 60 miles an hour.

The study group recommends that the NASA-DoD team develop a comprehensive research and development plan to improve orbital debris monitoring, modelling and data management capabilities. It also recommends that NASA and DoD develop a basic plan for generic technologies and procedures for minimizing debris and protecting spacecraft. Both plans are requested by January 1, 1990.

Don Kessler, a scientist at the Johnson Space Center's Space Science Branch and a member of the working group that prepared the debris report, said unless the amount of orbital debris created in orbit is constrained a 'critical density could be reached by the mid-21st Century. Critical density is the point at which the number of collisions creates a runaway increase that renders some altitudes unusable.

"It's something that needs to be looked at in more detail," Kessler said. "You don't want to be wrong one way or the other. If you're wrong about the possibility of losing LEO, then you've done a lot of work towards nothing trying to save it, but if you don't take it seriously you may end up losing LEO."

This computer graphic illustrates the vast swarm of debris that surrounds the Earth
ESA

Phobos Returns First Pictures

The Soviet Union's Phobos-2 probe has returned its first images of the Martian moon, Phobos. The probe is due to drop two landers onto the surface of the moon in early April.

The probe transmitted the first pictures of Phobos between 15:35 and 16:25 (all times Moscow Time) on February 21, when it was 860 to 1,130 km from the moon. The pictures were at first stored onboard Phobos-2, then relayed to Earth during a regular communications session. The images will provide information for the probe's more detailed examination of Phobos.

Before returning the pictures, Phobos-2 had been manoeuvred into a more circular 'observation orbit' at 17:06 on February 18. After completing the manoeuvre Phobos' engine unit was jettisoned. The probe will use its own low thrust motors to approach Phobos.

NASA Issues Call for Reuseable Satellite

The NASA Johnson Space Center (JSC), Houston, Texas has released a request for proposal for study and design of an unmanned reuseable reentry satellite that could significantly expand the agency's capability to investigate the weightless environment. The satellite, called "LifeSat" would be placed into orbit by expendable launch vehicles.

The satellite is planned to be almost completely reuseable and capable of being reflown within two months of the previous flight. Designs are expected to be derivatives of the often-flown Discovery, Gemini, and Apollo designs of the 1960s, calling for a vehicle roughly six feet in diameter, weighing over 2,000 pounds, and carrying a useful payload of 500 pounds.

The LifeSat would be used primarily in the fields of life sciences and materials processing and would fly experiments in a variety of orbits, including those incurring large radiation dosages, for periods up to 60 days. Upon completion of the flight, the spacecraft would soft-land at a ground site where scientists and engineers would have immediate access to the experiments.

Roelof Schuiling

Aurora Satellite

The Japanese Institute of Space and Astronautical Sciences has launched a satellite to study the Aurora Borealis, better known as 'the Northern Lights', and the Auroral Australis, the same effect, but occurring in the Southern hemisphere.

The satellite, named Exos-D, was launched by a M3-SII-3 solid rocket, from Japan's Kagoshima launch site on February 21. It was placed into high inclination orbit of 75 degrees, with a perigree of 300km and an apogee of 8,000km.

It is hoped the satellite will define the mechanism of the aurora particles.

Spacelab Payload Specialists Selected

Dr Ulf Merbold, European Space Agency (ESA) and Dr Roger K Crouch, NASA, have been selected as candidate payload specialists for materials sciences experiments on the International Microgravity Laboratory (IML)-1 mission aboard the shuttle Columbia in April 1991. NASA also announced that it has extended to the government of Canada through the Ministry cf Science and Technology an invitation to nominate two candidate payload specialists for the life sciences experiments on the IML-1 mission.

Dr Merbold flew as ESA's Payload Specialist on the Spacelab-1 Mission which was carried out in November/ December 1983. He is a soiid state physicist from the Max Planck Institute for Metals Research where his main fields of research was crystal lattice defects and low temperature physics. He jointed ESA in 1977.

After the initial training period, NASA will designate, in consultation with ESA, a prime and a backup payload specialist for the materials sciences portion of the IML-1 mission and will also designate, in consultation with the Canadian ministry, a prime backup payload specialist for the life sciences portion.

IML-1 is the first of a series of microgravity investigations using the Spacelab module. It will focus on material and life sciences, two disciplines needing access to a laboratory in reduced gravity. IML-1 will use the Spacelab long module and is a dedicated microgravity mission.

The investigations will use five life sciences experiments, designed to be used and flown again - Biorack, Protein Crystal Growth Facilities, Gravitational Plant Physiology Facility, Microgravity Vestibular Investigations and Space Physiology Experiments; and three materials facilities - Fluid Experiment System, Vapor Crystal Growth System, Mercury-lodide Crystal Growth System and the Critical Point Facility. These reusable facilities have been built by US, European, Canadian and Japanese investigators and organisations for reflight Critical Point Facility for thermodynamic studies under microgravity.

In addition to the experiments which require the reusable facilities, three other life science and three other materials science experiments with unique hardware will fly aboard IML-1.

The IML series are designed to fly at 17 to 25 month invervals. enabling investigators to analyse and understand the results of flight experiments and use that knowledge to design additional aboard the NASA-ESA Spacelab system.

ESA provides two major facilities for the IML-1 mission: the enhanced version of the Biorack of which a first version was already flown successfully on Spacelab D-1 in 1985 and the newly developed experiments.

Columbia will fly in a 160 (nautical) mile-high, 28.5 degree orbit. Mission duration is nine days and the crew will consist of two payload specialists and five additional astronaut/mission specialists. The orbiter will fly in a tail-down attitude called "gravity gradient" thereby producing the least gravitational disturbances on the Spacelab during the mission flight duration.

The IML series is intended as an ongoing international research programme in materials and life sciences in a microgravity environment.

Soviet Shuttle Cover

A philatelic envelope has been prepared by Mezhdunarodnaya Kniga, the Soviet export agency, in cooperation with Glavkosmos, the Soviet space agency, to commemorate the first test flight for the space shuttle Buran. The covers were not aboard the shuttle itself, but were at the Baikonour space facility for the launch and recovery.

The beautiful red and blue multicolour, printed cachet reads, "Multipurpose Reuseable Cosmic Ship," and the rubber stamp shows a line drawing of the space shuttle and reads "Experimental Flight 15.11.1988 Orbital Rocket 'BURAN'."

The postmarks on the Yuri Gagarin postage stamp are from the "Baikonour Cosmodrome" and are dated November 15, 1988. There are two postmarks, one for the launch and one for the successful landing at the space centre.

The back of each cover has a rubber stamp, with the legend in Russian and English, "Commemorative Cover Devoted to the Test Launching of 'Energia' Carrier Rocket and Space Shuttle Buran 15.11.88. Glavkosmos USSR and V/O Mezhdunarodnaya Kniga." Each cover is individually authenticated and signed by A. Ya. Belostotsky, General Director of Kniga, the official Soviet export agency.

Les Winick

Scout Agreement

NASA and the Missiles Division of LTV Missiles and Electronics Group, Dallas, Texas, have announced the signing of an agreement which grants the firm exclusive rights to commercially produce and market the Scout launch vehicle.

LTV has manufactured the NASA-developed Scout rockets since 1958 under a series of government contracts which procured flight vehicles in support of NASA science missions.

Under the new agreement, LTV is granted rights to produce and launch the Scout on a commercial basis and is provided access to NASA-controlled production tooling and special test equipment used in the production of the Scout rockets. The agreement also enables LTV to obtain the use of Scout launch support facilities at the NASA Wallops Island, Virginia, and Vandenberg Air Force Base, California launch sites.

The Scout launch vehicle became operational in 1960 and has undergone upgrading since 1976. The standard Scout is a solid-propellant four stage vehicle approximately 75 feet in length. The lift-off thrust is 132,240 pounds. Improvements have increased the Scout's capability to place payloads in low Earth orbit to approximately 210 pounds. Over 100 Scouts have been launched to date. They have placed payloads into inclined, equatorial, and polar orbits for a variety of missions.

Roelof Schuiling

SATELLITE DIGEST - 220

Robert D. Christy

Continued from the March 1989 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1974, 1988-92A, 19554

Launched: 2225, 3 October 1988 from Plesetsk, USSR by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stabilisation is probably by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1,800 kg.
Mission: Part of the USSR's ballistic missile early warning system.
Orbit: Initially 585 × 39,431 km, then raised to 586 × 39,784 km to ensure daily repeats of the ground track.

COSMOS 1975, 1988-93A, 19573

Launched: 0803, 11 October 1988 from Plesetsk, USSR by F-2.
Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1,600 kg. Stabilisation may either be by by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 631 × 666 km, 97.76 min, 82.54 deg.

COSMOS 1976, 1988-94A, 19582

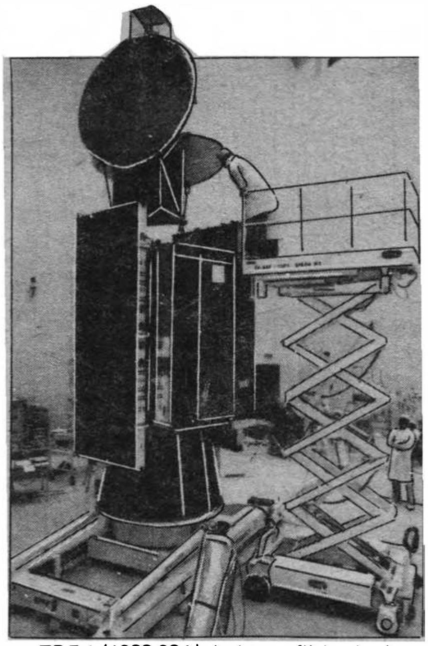
Launched: 1120, 13 October 1988 from Plesestk, USSR by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 359 × 410 km, 92.29 min, 72.86 deg.

RADUGA 22, 1988-95A, 19596

Launched: 1543, 20 October 1988 from Tyuratam, USSR by D-1-e.
Spacecraft data: Probably similar to the Gorizont satellites, being a stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2,000 kg.
Mission: Communications satellite providing continuous telephone, telegraphic and television links within the USSR.
Orbit: Geosynchronous above 35 deg east.

COSMOS 1977, 1988-96A, 19608

Launched: 1803, 25 October 1988 from Plesetsk, USSR by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stabilisation is probably by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1,800 kg.
Mission: Part of the USSR's ballistic missile early warning system.
Orbit: Initially 630 × 39,253 km, 708.23 min, 62.90 deg then raised to 634 × 39,728 km, 717.91 min, 62.90 deg to ensure daily repeats of the ground track.



TDF 1 (1988-98A) during preflight checks. The satellite was launched by Ariane on October 28, 1988. *Arianespace*

COSMOS 1978, 1988-97A, 19612

Launched: 1130, 27 October 1988 from Plesetsk, USSR by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor sytem. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 229 × 282 km, 89.66 min, 72.87 deg.

TDF-1, 1988-98A, 19621

Launched: 0217*, 28 October 1988 from Kourou, French Guiana by Ariane 2 (V-26).
Spacecraft data: Box shaped body with an aerial mast on one face, approx 2 m all round. Power is provided by a 19.3 m span solar array. The mass (in orbit) is 1318 kg.
Mission: French, domestic directbroadcasting television satellite.
Orbit: Geosynchronous above 19 deg west.

USA-33, 1988-99

Launched: 6 November 1988 from Vandenburg AFB, USA by Titan 34D.
Spacecraft data: not available.
Mission: Probably a pair of satellites in the Satellite Data System, used for military communications to and from northern polar regions.
Orbit: Approx. 600 × 39,700 km, 718 min, 63.4 deg.

BURAN F-1, 1988-100A, 19637

Launched: 0300*, 15 November 1988 from Tyuratam, USSR by K-1 (Energia).
Spacecraft data: Winged re-entry vehicle, 36 m long, with wingspan 24 m and fuselage diameter 5.6 m. The mass at launch was 105 tonnes.
Mission: Unmanned test flight of the Soviet Union's first shuttle orbiter. It landed on the Baikonur runway at 0625, after two circuits of the Earth.
Orbit: 248 × 256 km, 89.48 min, 51.63 deg.

2,000th Cosmos Launched

The Soviet Union launched the 2,000th Cosmos satellite on a Soyuz (SL-4) launcher from Plesetsk on February 10. Earlier the same day a string of military communications satellites, Cosmos 1994-1999, lifted off from Plesetsk, Cosmos 2001 was launched four days later.

The Cosmos series has become known as the 'catch all Cosmos'. The Soviets use it to categorise, many would say conceal, their military satellites, experimental spacecraft and launch failures. The first Cosmos satellite was launched on March 16, 1962, since then Cosmos launches have steadily increased, reaching just under 100 satellites per year.

Cosmos 2000's Earth resources mission includes mapping the central areas of Antarctica. Yuri Kiyenko, General Director of the State Research and Production Centre Priroda, said the satellite would provide unique data on the ice cover, on the outcrops of rocks and the formation of glaciers and icebergs. Also, new data might be obtained on the formation of the 'ozone hole' over the area. The satellite will also photograph areas of the Soviet Union.

A Tass statement, issued to commemorate the 2,000th launch, confirmed Cosmos 1374, 1445, 1517 and 1614 were the tests of the Soviet mini shuttle, which according to the statement: "were the first Soviet aerospace vehicles, which tested [the] heat protective covering for the Buran reusable spaceship".

BOOK NOTICES

The Moon Book

K. Long, Johnson Books, 1880 South 57th Court, Boulder, Colorado 80301, USA., 1988, 128pp, $6.95.

This paperback concisely summarises many fascinating facts about the Moon, including explanations of the times of Moonrise and Moonset, eclipses, lunar phases, Moon lore, lunar photography and the like.

It is very readable, filled with diagrams, and both erudite yet easy to understand.

The same publisher also issues a striking annual black and white poster-calendar, providing a graphic display of the phases of the Moon for each day of the year. It adds information on perigee, apogee, etc and is also available in card form. The poster size, 31½" x 20½", is available at $6.95, the card size, 6½" x 10½" at $1.95.

Annual Review of Astronomy and Astrophysics Vol. 26

G. Burbidge *et al*. Annual Reviews Inc., 4139 El Camino Way, PO Box 10139, Palo Alto, CA 94303-0897, USA. 1988. 703 pp. $51.

This volume contains sixteen contributions which provide authoritative reviews of some of the most active areas of astronomy and astrophysics today. The range, as ever, is extensive, beginning with a current view of comets in the wake of Giotto, the origin of the solar system, star formation and supernovae remnants and reaching finally to the large-scale structure of the Universe.

The information-content is invariably very high so, although the contributions would be valuable to any student or intelligent layman interested in astronomy, careful reading is essential if one is to make the most of the information imparted.

All contributions are carefully and fully referenced and prepared to a high standard.

A Manual of Advanced Celestial Photography

B.D. Wallis & R.W. Provin, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, England, 1988, 388 pp, £25.00.

Recent improvements in photographic emulsions, hypersensitization techniques and telescopic equipment have made it possible for amateurs to make real contributions to astronomy. This is a unique technical handbook which brings together topics generally not available to the non-specialist, thus bridging the gulf between the novice and the advanced astrophotographer. It includes a detailed discussion of topics not usually mentioned in general surveys, e.g. photographic optics, instrument design, techniques at the telescope, films and developers, advanced darkroom methods, sensitometry and film hypersensitization. Emphasis is placed on understanding basic photographic principles and professional laboratory methods.

A number of special techniques are discussed which add to the comprehensive nature of this work and have the aim of encouraging readers to obtain celestial photographs of a high order.

ETI A Challenge for Change

P. Schenkel, Vantage Press Inc., 516 West 34th Street, New York, NY 10001, U.S.A., 1988, 248 pp, $16.95.

In this book the author postulates what contact with advanced intelligent life and other planetary systems could mean to mankind. He believes that such life exists and urges increased SETI efforts.

Part I examines some of the economic and political problems facing mankind today, hence a fair amount of comment on the current political scene and the inclusion of all sorts of political worthies in the index. Part II not only supports the idea of the existence of extraterrestrial intelligence but stresses the probability that this is likely to be more advanced than we are, both in technology and in other respects. The author argues that older civilizations must necessarily have undergone similar evolutionary stages to ourselves and propounds the view that such meetings would be highly beneficial to mankind.

Satellite Astronomy: The Principles and Practice of Astronomy from Space

J.K. Davies, John Wiley & Sons Ltd., Baffins Lane, Chichester, West Sussex, PO19 1UD, England, 1988, 198 pp, £34.50.

Satellites are now the key tools in astronomy which have revolutionised the way in which we perceive the Universe. This book provides a comprehensive review of how astronomy is now carried out from space and examines, in some detail, those historic missions which provided the quantum leaps in our ability to observe and understand the Universe.

It begins with an introduction to the basic principles, operational methods and engineering challenges posed by space astronomy. This is followed by chapters which describe the use of satellites for investigating various regions of the electromagnetic spectrum. The main types of instruments applicable to each energy band are described and several important satellites and their results reviewed in detail. Additionally, a number of smaller missions are summarised and guidance given as to further reading.

Each chapter concludes with details of further missions already approved and due for launch over the next few years. A final chapter examines a developing role expected for astronomical satellites over the next century, including instruments attached to space stations and installed on the Moon.

Guidance and Control 1988

R.D. Culp & P.L. Shattuck, Univelt Inc., PO Box 28130, San Diego, CA 92128, U.S.A., 1988, 576 pp, Hard back $75, Soft back $60.

This book, Vol. 66 in "Advances in the Astronautical Sciences", is based on a conference held early in 1988. Sections include spacecraft attitude control and autonomy, guidance and control storyboards displays, space station system control techniques and offboard navigation and attitude systems.

Astrodynamics 1987

J.K. Soldner *et al*, Univelt Inc., PO Box 28130, San Diego, CA 92128, U.S.A., 1988, 1774 pp, Hard back $180, Soft back $150.

This volume, in two parts plus a microfiche supplement, presents the proceedings of the latest of a series of annual Astrodynamics Conferences, held in August 1987. Wide-ranging session topics included space transportation, LEO orbit determination, optimal control, gravity assist missions, precise orbit determination, multibody dynamics and tethered satellite, the NASA Mars exploration programme, semianalytic satellite theory, a special NORAD session, structural identification and control, planetary mission and payload analysis, satellite debris and orbit decay, dynamics and control of rotating structures and outer planetary exploration.

The Cambridge Atlas of Astronomy

J. Audouze and G. Israel, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, England, 1988, 431 pp, £35.00.

The exploration of our Universe is one of the great intellectual adventures of the present age. Telescopes on the Earth and in space have enabled us to see the stars as never before, to perceive our own galaxy more clearly and to penetrate the vast reaches of space. Radiation of all types collected by modern instruments e.g. light, radio waves, x-ray and ultraviolet radiation, when analysed by the latest image processing techniques, has provided a new perspective of star formation, interstellar matter and the turmoil which takes place within active galaxies and quasars.

This second edition of an outstanding compendium of information contains results from the most recent space missions such as the Voyager 2 encounter with Uranus, the Giotto mission to Halley's Comet and the series of Soviet spacecraft used to explore Venus and its atmosphere. It has been extensively revised and brought completely up to date.

The atlas provides detailed information on planetary science, modern astronomy and astrophysics and cosmology generally. Many of the illustrations have been computer-processed to emphasise features of significance. There are 350 colour photographs, 420 in black and white and over 300 other illustrations prepared specially for the book, all accompanied by extensive captions.

Quasars, Redshifts and Controversies

H. Arp, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, England, 1988, 198 pp, £12.50.

In this book the author contests the accepted view that quasars are the most distant objects in the universe and presents observations and data to explain why he has concluded them to be associated with relatively nearby galaxies.

He takes the view that the enormous redshifts of quasars do not arise from the expansion of the universe but are an intrinsic property of the quasars themselves, adding that galaxies and quasars probably have an origin far different from that assumed by the "Big Bang" model of the universe.

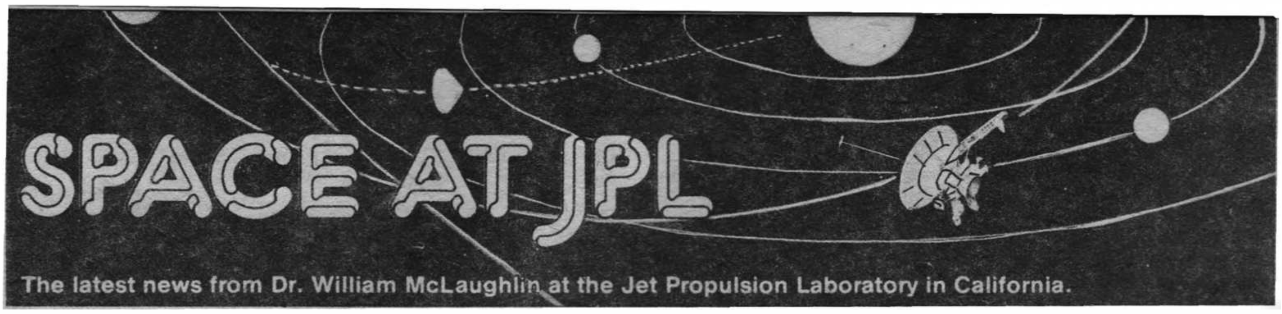
The Guide to Amateur Astronomy

J. Newton & P. Teece, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1988, 327 pp, £15.00.

Amateur astronomy is still an area of scientific activity where modest equipment can offer the chance of making exciting discoveries.

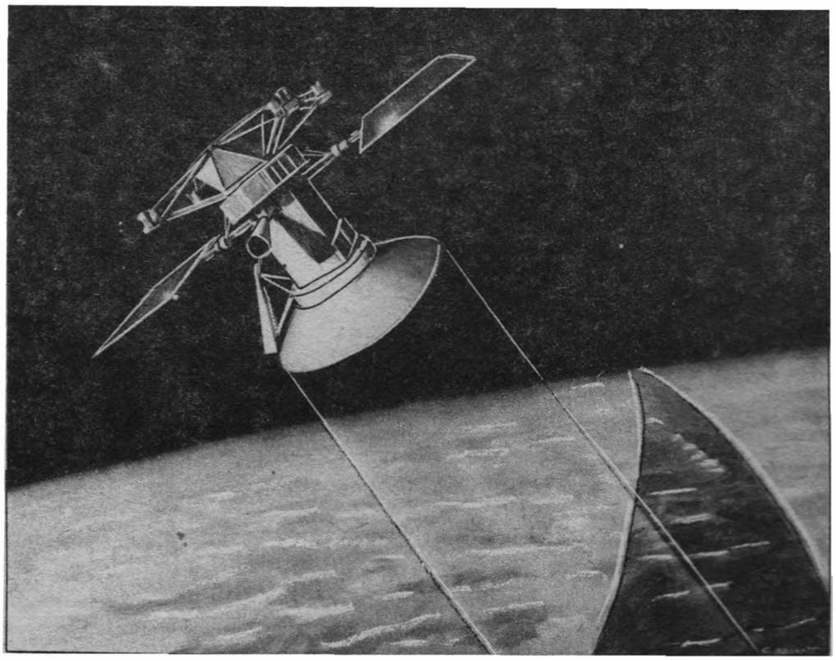
This book introduces the fundamentals of astronomy and explains how one can get started in making one's own observations. It includes maps of the night sky to help with indentification, as well as information on how to recognise and locate planets.

After acquiring some basic knowledge, a new observer will wish to turn to some of the more advanced projects described in the book. An important feature is the emphasis placed on practical techniques, including how to build a telescope from first principles, make an observatory for it and experiment with astro-photography. Other areas lie in observing variable stars or using a personal computer. There are plenty of additional suggestions for investigation, including asteroid and comet hunting, nova and supernova searches, observing binary stars, etc.



Magellan to Venus

For thirty years the primary assignment of JPL has been to conduct unmanned exploration of the Solar System within the NASA programme. However, no JPL-managed missions have been launched to the planets since Voyagers 1 and 2 in 1977. Thus, the scheduled lift-off this month or in May of the Space Shuttle Atlantis, carrying the Magellan spacecraft mated to an upper-stage rocket, is not only an event of scientific importance but also constitutes a refreshment of the Laboratory's prime purpose. The feeling of refreshment is broadly based since, as I write this piece in January, President Reagan's budget submission to Congress includes a project start in Fiscal Year 1990 for the first two Mariner Mark II missions: Comet Rendezvous Asteroid Flyby (CRAF) to Comet Kopff and Cassini to Saturn.



In this artist's concept, the Magellan probe orbits Venus, mapping the surface of the planet.
Martin Marietta

New beginnings are certainly not unique to the space programme, but they are often more visible in such a progress-oriented endeavour. When I joined the Apollo lunar-landing project in 1968, recovery from the devastating fire of 1967 which killed three astronauts was well underway, and the Christmas circumnavigation of the Moon by Apollo 8 dramatically certified that fact (along with the October 1968 flight of Apollo 7). Similarly, one can view the Magellan launch as a healing event for the trauma inflicted on planetary exploration by the explosion of Challenger in 1986. For me, the cumulative low point was reached after the Challenger's destruction when I walked through the flight-team areas of Galileo and Ulysses, scheduled for May 1986 launches (Galileo is now rescheduled for October 1989 and Ulysses for October 1990). The sense of lost opportunity was a palpable companion for the people who sat in those offices and tried to guess what an uncertain future would bring.

Prior to the Challenger accident, Magellan was scheduled for an April 1988 launch — almost two years after Galileo's and Ulysses' planned ascents — and consequently the project was earlier in its development cycle. Hence, while Galileo and Ulysses had to de-staff many positions, Magellan adjusted its build-up profile. (The modifications to the Galileo spacecraft have also been extensive since it must now be equipped to survive the thermal rigours of the inner Solar System while receiving a gravity assist from Venus; see the May 1987 "Space at JPL" for these changes and last month's column for some scientific plans which this outer-planet mission has formulated to take advantage of the 15,000 km flyby of Venus in February 1990.)

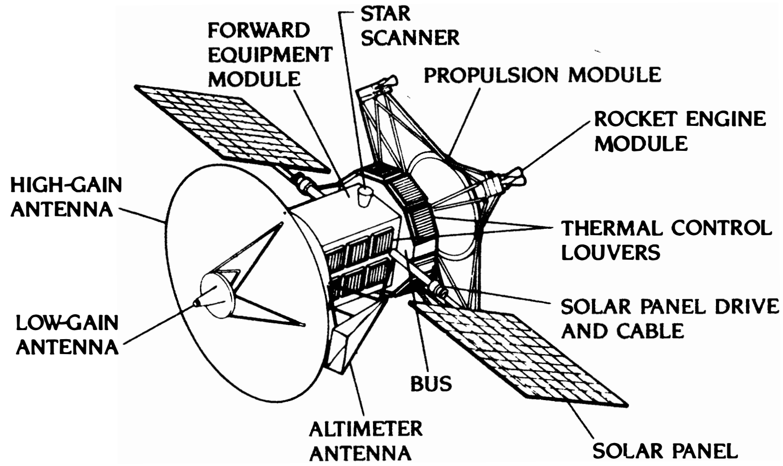
Space exploration is a feasible and rewarding activity, as the record attests, but it often poses a series of challenges that manifest themselves as threats to a schedule. In order to meet President Kennedy's goal of a successful lunar expedition by the end of the decade, Apollo managers had to juggle flight schedules to suit the occasion. For example, the Apollo 8 circumnavigation of the Moon was a late interpolation between the Earth-orbiting Apollo 7 and 9 missions, designed to accommodate the current state of hardware development and stay on the critical path to the first lunar-landing mission. Magellan has built its schedule not to conform to a presidential mark but to meet the realities of planetary alignments and Shuttle manifests.

Magellan experienced two hardware challenges to its schedule when, in October 1988, a short-lived but intense battery fire took place just after the spacecraft arrived at the Kennedy Space Center (KSC) and later in the year when fabrication flaws were detected in portions of the radar and spacecraft-data subsystems. Through the fall and winter, project personnel added work shifts and eliminated holidays to recover lost time.

The rectification of these two problems had to be accomplished against a background of scheduled work; the business of readying a spacecraft for launch is an intensive activity. In order to keep abreast of progress, I subscribe to the daily spacecraft status reports, issued from the project office at KSC. One or two pages are spent on these high-level summaries wherein, typically, accurate measures of mass and centre-of-mass are compared with previous estimates, electronic components tested, compatibility of spacecraft and ground systems veri-

fied, and apparently anomalous measurements explained.

James S. Carter was Deputy Chief of the Sequence Team (responsible for generating command loads for the spacecraft) for Project Galileo in 1986 when the mission was delayed. Carter's previous experience had included service with the Viking and Voyager projects, and, with the Galileo destaffing in this area, his experience was transferred to Magellan's flight team. He is the Chief of that project's Mission and Sequence Design Team (MSDT), and he briefed me on Magellan-in-cruise, as reported below.



The Magellan probe.

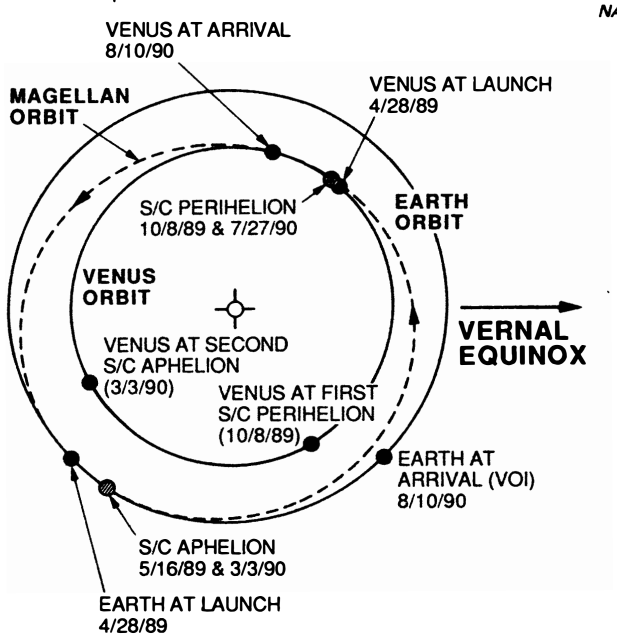
After launch, and up to the August 1990 arrival at Venus, the spacecraft will be in interplanetary cruise and, unlike cruise phases for most missions, scientific experiments will not be undertaken (the spacecraft's payload, a synthetic aperture radar and an altimeter, are designed for planetary mapping applications). However, just as during the period of the spacecraft's residence at KSC, engineers on Carter's MSDT and other flight teams will be kept busy maintaining and conditioning the vehicle for its future rendezvous with Venus — see the September 1987 edition of this column for a review of the Venusian survey strategy.

The MSDT occupies an intermediate position on Magellan's flight team, between the Mission Planning Team and the Spacecraft Team. The Mission Planning Team considers scientific options and engages in long-term mission analysis, including possibilities following the prime (243-day) mapping mission. The results of these analyses are expressed, in the main, in a continually updated Mission Plan. Accepting the Mission Plan as input, the MSDT produces as its primary output the "Skeleton Orbit Profile" (SOP). As the name implies, the MSDT unit of planning, during Venusian orbital operations, will be the orbit; the spacecraft swings in an eccentric orbit about Venus every 3.15 hours, mapping the surface of the planet with its radar at lower altitudes near periapsis and then turning toward Earth to pump the recorded data back to the antennas of the Deep Space Network. The SOP is fed to the SpacecraftTeam for the production of the actual sequence of commands which are radioed to the spacecraft.

The building blocks for a SOP are called, fittingly, "blocks". The blocks are a standard set of subroutines into which the MSDT inserts the appropriate parameters in order to achieve desired performance of the spacecraft (and cues for supporting actions on the ground).

The spacecraft must be cared for during its year-plus cruise to Venus. Carter detailed some of the more important responsibilities with which he and his team are charged.

The Magellan spacecraft will wrap itself around the Sun about 1.6 times in its cruise from Earth to Venus.
NASA/JPL



Two fundamental activities are placing periodic "STARCALS" and "DESATS" in the SOP; both relate to controlling the attitude (orientation) of the spacecraft. In the STARCAL, stars are observed by means of the spacecraft's star sensor in order to correlate accurately the internal reference system of the vehicle with the external world.

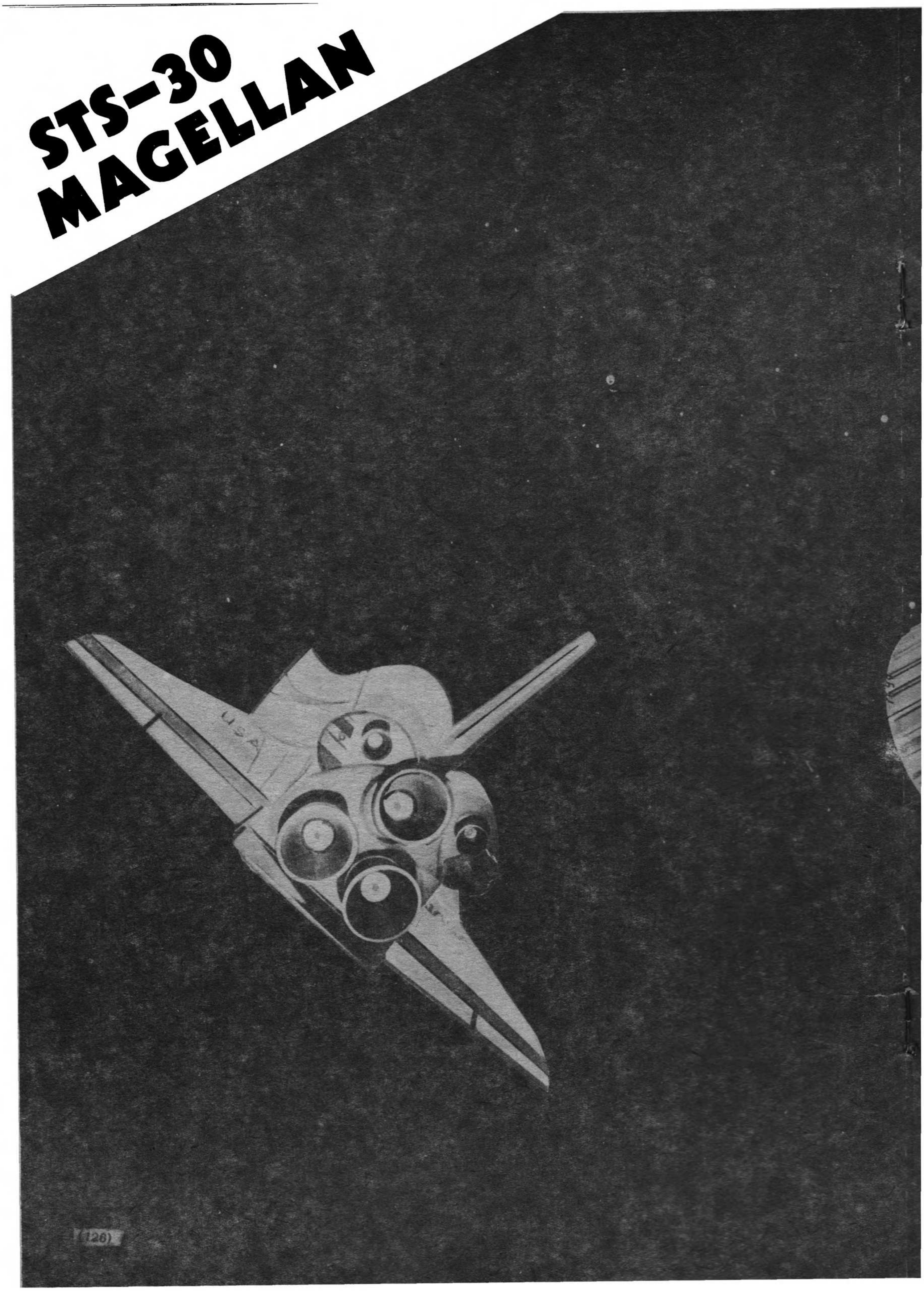
The DESAT function refers to unloading (desaturating) excess momentum from the reaction wheels. The three reaction wheels store angular momentum (derived from the electrical energy generated from the solar panels) used to place the spacecraft in its desired attitude; changing the angular velocities of the wheels in a calculated manner will turn the spacecraft to a new attitude. In the course of time, holding the spacecraft's attitude under buffeting by the solar wind, and similar disturbances, will result in one or more of the wheels spinning at a rate which approaches the design limit. Hence, momentum is proportionately removed from the set of wheels by a DESAT to return the system to a state well within its normal operating range (physically, the spacecraft's hydrazine thrusters are used to accomplish the momentum unloading).

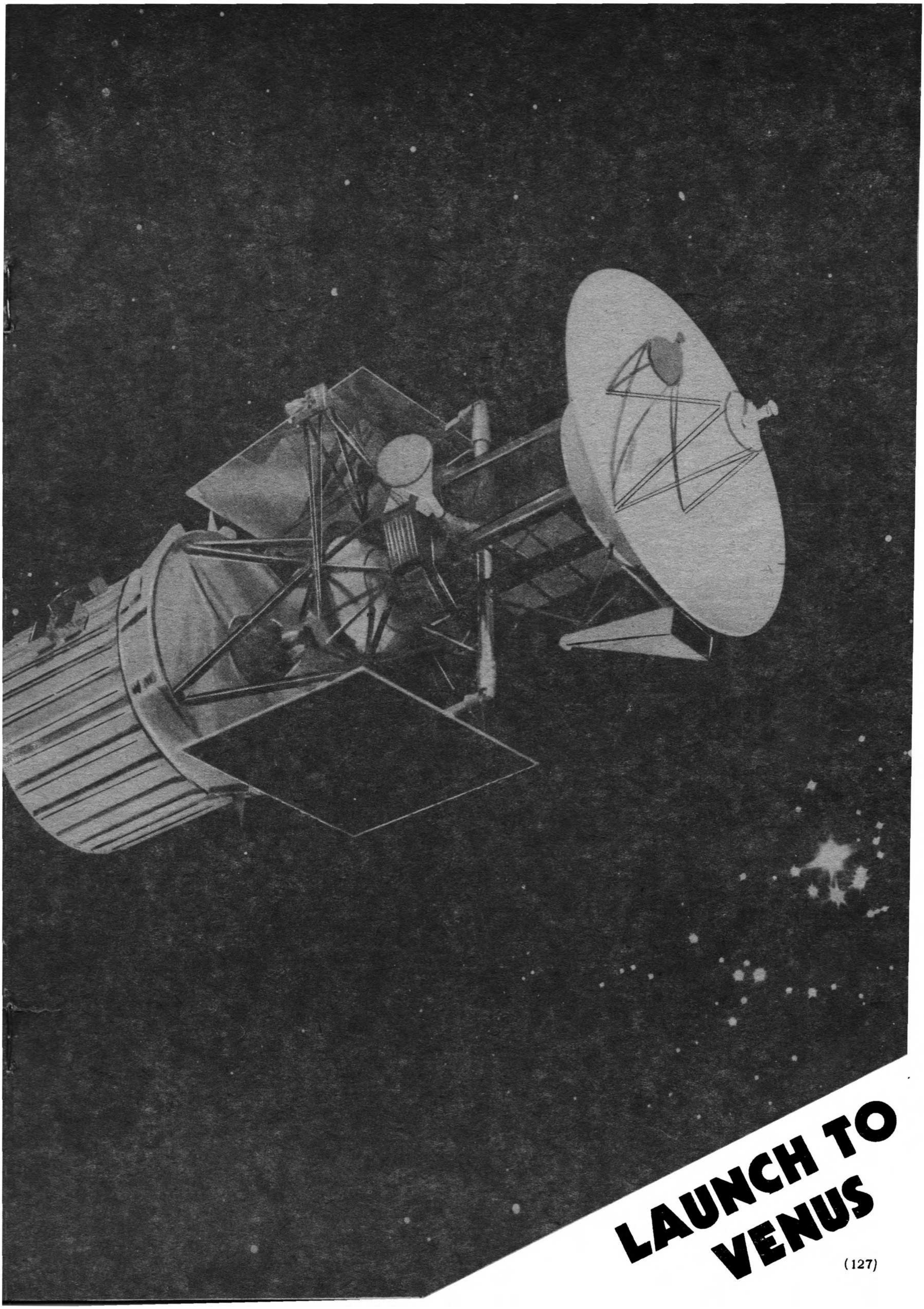
The STARCALS and DESATS (Carter said that informally the team has labelled the dual activities "DECALS") will be done about once per day during the initial portion of the cruise, relaxing to every other day after about three months. While the unit of orbital planning is 3.15 hours in length, each cruise SOP is about two weeks long, yielding a rough measure of relative complexity between orbital and cruise operations.

A key ingredient in most missions is the set of trajectory-correction manoeuvres (TCM) which will maintain the spacecraft on its proper course. Just

Continued on p. 128

STS-30 MAGELLAN





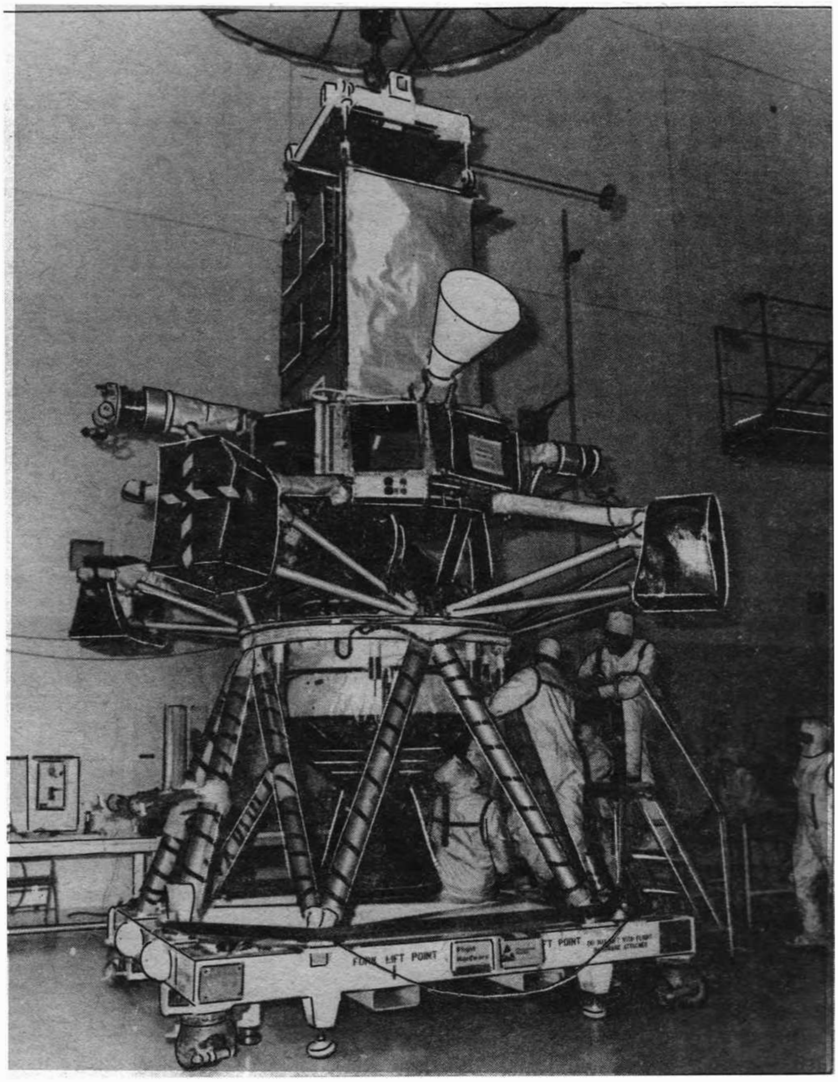
LAUNCH TO VENUS

Continued from p.125
as angular momentum is employed to manage the attitude of the spacecraft, linear momentum, generated by the familiar method of mass expulsion through a "motor burn", is used to adjust the trajectory. Prior to insertion into orbit about Venus, three TCMs are planned for Magellan. The first, scheduled for about 15 days after injection into interplanetary cruise, will clean up any small errors resulting from that injection burn. The second, approximately one year into cruise, will also serve as a cleansing agent, as will the third, about 17 days prior to insertion into orbit about Venus. The transfer from interplanetary cruise to a planetary orbital trajectory is accomplished by igniting a STAR 48 solid-rocket motor.

The solid-rocket motor must be tended during cruise by providing it with the proper thermal environment. When far from the Sun, the STAR 48 is warmed by adjusting the spacecraft attitude so that the Sun shines on the motor; nearer to the Sun, shading is required.

No data will be acquired by the synthetic aperture radar during cruise, but the spacecraft's tape recorder will be supplied, prior to launch, with a load of radar data. These data can be played back during cruise (the plan is to do this three times) for the purpose of exercising computers and people on the ground, prior to orbital operations.

Five days a week, eight hours per day, Carter's team and other elements of the flight team will guide Magellan to Venus for its mission of scientific exploration. We wish them all well in that most exciting undertaking — the exploration of space — and see in Magellan a celebration of the return to deep space.



The STAR 48 solid-rocket motor is mated to the Magellan probe. *NASA*

Burning Curiosity

With Voyager 2 bearing down on Neptune for a flyby in August, curiosity becomes a factor in our anticipation of that event. Does Neptune have rings? If so, are they partial arcs? Will we be able to see the surface of the large satellite Triton? If so, will it have lakes of liquid nitrogen? Will the spacecraft receive a strong dose of radiation from trapped particles?

Several times in the last three years I have tried to express, verbally and in writing, the experience of watching Uranus draw near, from the vantage of Voyager 2. I will try again. It seemed to me, and still does, the most exciting thing in the world: the seventh circle of curiosity. Two TV monitors sat on my desk at JPL, principally for monitoring spacecraft telemetry channels, but when images were coming down I frequently switched over to see them. As the spacecraft approached the Uranian system, the satellites were transformed from points of light to disks with obscure features. A white blur on Miranda gradually took form and, in the closest-approach images, became a chevron imbedded in some of the most bizarre topography in the Solar System. The "Columbus experience" has been invoked on many occasions but none more appropriate than here. The drama will repeat at Neptune.

Several years ago (see the August 1980 *JBIS*) I became interested in the history of discovery relating to planetary rings. Rings were discovered in 1610 (Saturn), 1977 (Uranus), and 1979 (Jupiter). These dates, particularly the last two, represent the termini of discovery — the satisfaction of curiosity — but what transpired in the prediscovery period? Frequently we find ourselves struggling with unresolved problems and failing to learn from the completed tasks of the past.

When Galileo observed Saturn through his telescope, he did not realize that the objects he saw were rings. In fact, it fell to Christian Huygens in 1655 to deduce the true nature of the Saturnian rings. But with the Saturnian example in hand, theoreticians and observationalists poked for the next few centuries at the possibility of rings about other planets.

The Jovian rings were discovered from Voyager 1 by direct imaging as the spacecraft passed through the equatorial plane of Jupiter. Prior to that time, Jovian rings were predicted on theoretical grounds in 1962 by the Soviet astronomer S.K. Vsekhsvyatskii and, using different assumptions, by Hannes Alfvén (1972) and J. Boynton (1975). Analyzing charged-particle data from the Pioneer 11 flyby of Jupiter in 1974, Mario Acuna and Norman Ness perspicaciously saw the possibility of a ring about Jupiter.

Prediscovery evidence for the rings of Uranus has an even longer history. The discoverer of Uranus (1781), William Herschel, noted in his journal in 1787, "the suspicion of a ring returns often when I

adjust the focus." (It is likely, however, that Herschel was responding to a defect in the optical system of his telescope.) A probable prediscovery observation of the rings was made by a balloon-borne telescope, Stratoscope II, in 1970, but recognition of this fact did not occur until 1977, following the actual discovery, when special data processing techniques were used to search for signs of the newly discovered rings Alfvén also predicted, as in the case of Jupiter, rings about Uranus.

The Uranian rings were detected from Earth by observing the occultation of a 9th magnitude star, SAO 158687, by the planetary system. Dips in brightness were correctly interpreted as being caused by rings about the planet, and, in the next few years, the ring system was quite accurately mapped by the occultation technique The same method has been employed with regard to Neptune, but the results have been less conclusive (see, for example, a paper by C.E. Covault *et al.* in *Icarus 67*, pp. 126-133, for some of the observations) Neptunian ring hunting has, like the Uranian case, a long history, e.g., in 1847 J. Challis used an 11¾ inch refractor at Cambridge to "detect" rings about Neptune (like Herschel's Uranian rings, the observation is almost certainly invalid, unless these objects have very great temporal variation).

The prediscovery histories of the planets Uranus, Neptune, and Pluto make a fascinating story from which many methodological morals can be extracted (see "Juggling Numbers" in the September 1988 "Space at JPL" for some connections with the Titius-Bode law). But my favourite example of burning curiosity concerns the long trail of investigation that led from puzzlement to an understanding of the source of the Sun's energy. Trust me and read on; the history is far superior to the pun.

Mankind had been curious about the source of solar energy, as part of the general development of a scientific world view, but it was not until the middle of the nineteenth century that an explanation became imperative. The problem arose from a conflict between physics on the one hand and biology and geology on the other. Julius Mayer, Hermann Helmholtz, and James Joule had formulated, in the 1840s, the law of the conservation of energy — one of the grandest generalizations of physics. Mayer and Helmholtz postulated that the gravitational contraction of the Sun was the source of solar energy and, using conservation of energy, calculated the required rate of contraction (somewhat over 200 feet per year). More importantly, it was shown that through contraction the Sun could only meet its energy needs for a few tens of millions of years.

But even prior to the solar-lifetime estimates, the geologist Charles Lyell had dated the oldest fossil-bearing rocks at 240 million years, and the work of Charles Darwin in evolutionary biology added weight to the geological testament. The astronomical and geological estimates were clearly at variance.

An alternative to solar contraction was entertained by some. the infall of meteors onto the solar surface. However, it was soon realized that an impossibly high flux of meteors would be required to maintain the Sun's temperature.

It is interesting to track the subject, over the years, through the lens of popular works on astronomy as authors wrestled with the astronomical/geological contradiction and then, slowly, saw hope in the mysterious subatomic phenomena that came upon the scene towards the turn of the century.

Thus, Joel Dorman Steele in his *New Descriptive Astronomy* (1884, p.54) ignores the geological problem and states, "The heat of the sun is generally considered to be produced by condensation, whereby the size of the Sun is constantly decreasing, and its potential energy thus converted into kinetic."

In a more careful analysis, *A Textbook of General Astronomy* (1889), Charles A. Young rejects the meteoric theory as insufficient and says (p.223), "We seem to be shut up to the theory of Helmholtz, now almost universally accepted; namely, that the heat necessary to maintain the sun's radiation is principally supplied by the slow contraction of its bulk." Despite some discomfort evident in his phrasing, Young makes no explicit reference to the geological evidence.

In his popular work, *The Stars* (1901), the astronomer Simon Newcomb does explicitly note (pp.224-225) the conflict between geological estimates and the conclusions of the contraction theory and makes an oblique reference to alternative modes of energy generation: "Facts are accumulating which converge to the view that forms of substance exist which are neither matter nor ether, but something between the two — perhaps primeval substance from which matter was evolved. In this ethereal substance is stored an almost exhaustless supply of energy." Recall that in 1896 Antoine Becquerel had discovered "Becquerel rays" emitted by uranium salts. And, in his *Side-Lights on Astronomy* (c. 1906), Newcomb says (p.59), "Who knows but that the radiant property that Becquerel has found in certain forms of matter may be a residuum of some original form of energy which is inherent in great cosmical masses, and has fed our sun during all the ages required by the geologist."

By 1912, Young in his *Manual of Astronomy* has been partially weaned from the contraction theory. Although on page 254 he says, "[the contraction theory] has high probability in its favour," on page 570 he admits, "radium and its congeners may have played an important part, and the sun's age may be many times greater than the limit we have named."

Concluding our survey of popular attitudes on solar energy generation, we find that by 1934 the tide has definitely turned away from support of the contraction theory, with Edward Fath (*The Elements of Astronomy*, third edition, p 117) summarizing, "Various theories to account for the maintenance of the solar radiation have been proposed, but the only one which seems worthy of consideration at the present time is the one which places the source in the disintegration of the atoms of the sun's mass. Much still remains to be done before this theory can be considered as proved, but it appears to be the only one which will account for the radiation of the sun for the period of time which now seems necessary." He was apparently referring to fission, rather than the fusion processes which actually power the Sun and stars, but the basic issues were settled.

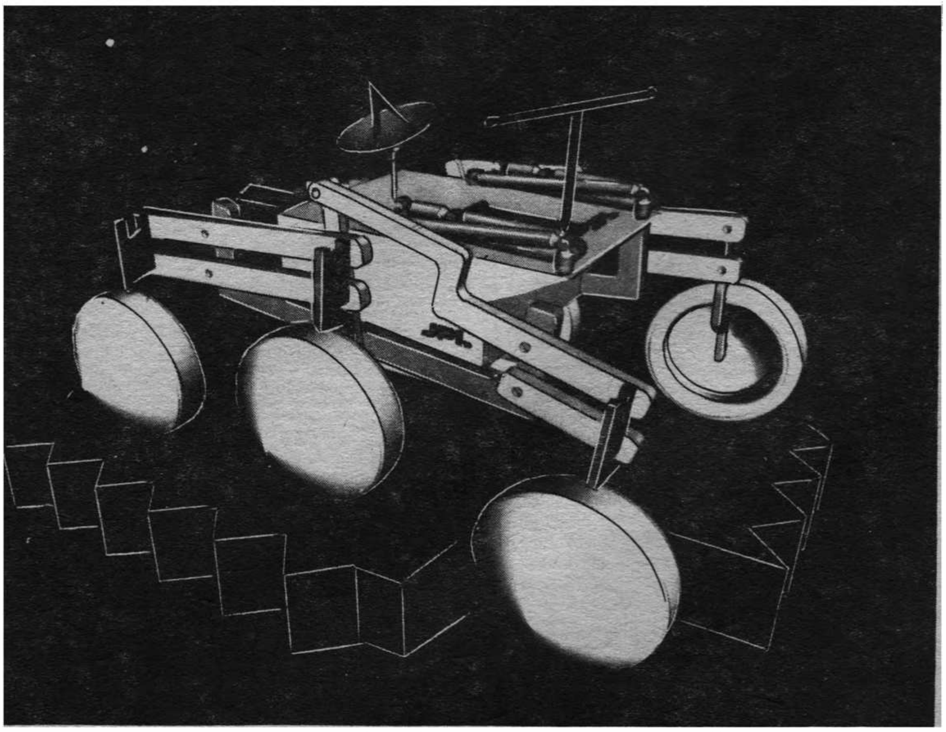
We started out by contemplating the Voyager 2 exploration, this coming August, of the Neptunian system and detoured through previous adventires in ring discovery and the source of the Sun's energy. No certain rules of discovery are apparent, but the mathematician George Polya in his classic *How to Solve It* (1945) lists "have you seen it before?" as one of his basic precepts for discovery. Perhaps exercises, such as the above, help to build intuition by stocking our minds with material so that we are better equipped to follow Polya's guidance. Well — does Neptune have rings? (I said "yes" in my 1980 paper.)

Roving on Mars

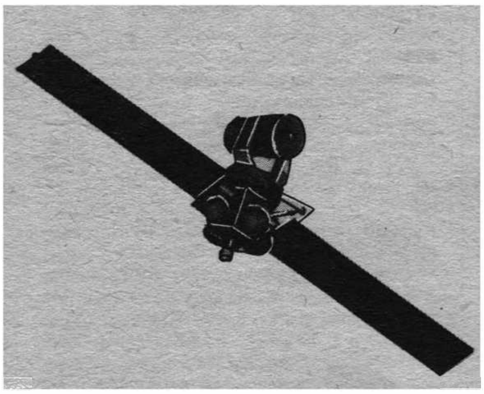
The age-old fascination with Mars is once more asserting itself. The Red Planet burned bright in our night skies last year — the most favourable opposition in many years — stimulating ground-based telescopic studies. The Soviet Phobos mission is underway, and NASA's Mars Observer mission is scheduled for a 1992 launch. Even more ambitious plans are being made by U.S. and Soviet mission planners with regard to the exploration of the planet. Given the persistent interest in Mars and the continuing growth in space technology, intensive investigation of the surface, by humans and machines, seems only a question of time. The Mars Rover Sample Return (MRSR) mission is being studied by NASA as an option for the late 1990s, with a launch that could occur as early as 1996 (sending the first portion of the MRSR system elements to Mars).

Since MRSR was last reported on in this column (November 1987), the joint study, by the Jet Propulsion Laboratory and NASA's Johnson Space Center, has made notable progress. Much of this progress was documented in 17 papers given at the AIAA Aerospace Sciences meeting in Reno, Nevada, in January. The mission of MRSR is centered upon returning about 5 kg of Martian surface samples to Earth, and its technical challenges are considerable, but, the study has shown, they appear to be within the grasp of current technological capabilities.

The objectives of MRSR are broad and



A descendant of this conceptual design for a Rover may traverse the surface of Mars around the turn of the century if the Mars Rover Sample Return (MRSR) mission is approved. *NASA/JPL*



A Mapping and Communication Orbiter (MCO) is planned for deployment in an elliptical orbit about Mars as part of the proposed Mars Rover Sample Return (MRSR) mission. *NASA/JPL*

fall into two basic categories: (1) scientific studies relating to geology, climatology, and biology, and (2) experience which will prepare the way for the eventual human exploration of Mars. Factors in the second category include environmental information and the testing of key engineering technologies.

Four major elements of the MRSR system have been identified: (1) Rover, (2) Mapping and Communication Orbiter (MCO), (3) Sample Return Orbiter Segment (SROS), and (4) Mars Ascent Vehicle (MAV). The combined mass of these elements would require a launch vehicle with heavy-lift capability, such as the proposed Advanced Launch System (ALS) or the proposed Shuttle C. Consequently, in order to base the mission upon existing launch vehicles, most of the mission scenarios which have been developed utilize more than one launch to transfer the elements from Earth to Mars. Quite satisfactory element packaging and delivery can be achieved with Titan IV/Centaur G launch vehicles.

Upon arrival at Mars, two options exist for insertion into orbit about the planet: propulsive and aerocapture. One mission scenario packages the MCO and SROS in one Titan/Centaur launch, separates them after launch, and propulsively inserts each into Mars orbit. In the same scenario, the Rover and MAV go up in a second Titan/Centaur launch and employ aerocapture techniques to achieve orbit about Mars.

Once in orbit, the MCO will observe 10 × 10 km potential landing sites to provide information for site selection. The imaging resolution to support this process will be about 0.25 m per picture element (pixel). Later, the MCO will also serve as a telecommunications relay satellite, linking elements on the surface of Mars to antennas on Earth. An elliptical orbit is prescribed for the MCO; the low periapsis (250 km altitude) facilitates imaging, and telecommunications functions are performed in the upper reaches of the orbit.

Two different kinds of surface operations are being studied: local and areal. In the local scenario, a modest Rover would be landed together with the MAV, and the Rover would collect samples within a region extending no further than 100 m from the MAV. The areal approach envisages the Rover and MAV either landed together or separately. The Rover range would be much greater than for the local option, travelling 20 to 40 km for sample-collecting activities.

In several months on the surface, sample collecting will be effected by a variety of methods: raking (for pebbles), scoops of soil, collection of individual rocks, sampling portions of rocks, and core samples of the regolith at a metre or more in depth. The latter mode might be accomplished by special equipment onboard the MAV rather than the Rover.

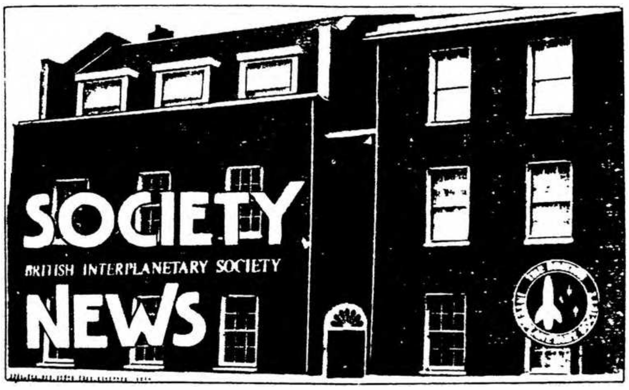
Several technologies are being investigated to develop an efficient Rover. Two general schemes for directing the Rover are applicable to both the areal and the local regimes: computer-aided remote driving (CARD) and semi-autonomy. In the CARD method, an operator on Earth makes decisions based upon stereo pictures taken by the Rover. The Earth-based operator examines the images and selects a safe path for the next leg of traverse (up to 30 m) for the Rover. A prototype CARD-operated vehicle has been tested in the Arroyo Seco near JPL — it is an interesting experience to be carried along dirt roads in a vehicle intermittently directed by an operator one quarter of a mile away! The CARD method results in rather slow traverse of the Martian terrain; progress is limited by the round-trip light time between Earth and Mars, the necessity of an Earth-Mars communications link, and the time required for Earth-based decision procedures. Semi-autonomy is more technologically ambitious but would yield a greater effective range for the Rover. It relies upon high-resolution, three-dimensional information extracted from MCO pictures and stored onboard the Rover. Sophisticated Rover software would move the Rover through the terrain, sending imaging reports of progress back to Earth, but only halting its autonomous journey if an impasse of some sort were reached (the Rover would halt from time-to-time during normal traverse to do its own route planning).

The physical mode of locomotion of the Rover could be one of several types now under investigation. Wheels or legs are obvious candidates (see the November 1987 and November 1988 editions of this column for illustrations of both classes). One imaginative concept, "the walking beam", is constructed of two nested tripod platforms. The platforms are alternately translated with respect to one another in order to produce motion.

Upon completion of surface activities, the MAV will lift off the surface of Mars and dock with the SROS. An Earth Return Vehicle (ERV), part of the SROS, will carry the sample back to terrestrial laboratories for analysis. Near Earth, a Sample Return Capsule will be separated from the ERV and either placed in Earth orbit or sent directly to the surface via parachute.

The rationale for a Mars sample-return mission has been presented in some detail in *Planetary Exploration through the year 2000: An Augmented Program* (U.S. Government Printing Office, Washington D.C., 1986, pp. 58-101). An obvious benefit of a sample-return mission over *in situ* studies is that the full force of scientific judgement and technology can be brought to bear on a wide variety of problems: chemical, geological and biological. The analyses can continue to yield scientific results for years, as the Apollo lunar samples have shown, including investigation of questions that arise long after the mission is complete.

A strong team within government and industry has been formed to make feasible the return of a rich Martian inventory around the turn of the century. Their results indicate the technological directions that would lead to success, and the scientific value of the undertaking is clear. Approval of MRSR as a project awaits a larger set of decisions concerning NASA's next big step in the exploration of the solar system.



President For 1989

At the Council meeting held in late February Mr. G.W. Childs was unanimously re-elected President of the Society for a second annual term of office.

Mr. G.W. Childs

After his re-election Mr. Childs said, 'I look forward with confidence to the Society continuing to play an important role in promoting the advancement of astronautics in the year ahead. 1989 promises to be a year of significant new developments for space technology and applications in an improving international climate'. Enlarging on the role of the Society, he said, 'The contribution of individuals will continue to count for much of what is achieved and the Society, as a long-standing Learned Body, has a vital role to play in support of the work of the individual through its programme of meetings, publications and other activities'.

At the same Council meeting the two offices of Vice-President were filled for 1989 by the re-elections of Mr. A.T. Lawton and Professor I.E. Smith.

JBIS — A Leading Journal

Members who receive *JBIS*, the Society's main technical and scientific publication, will have noted that a number of changes have been introduced over the last year or two to the journal's general presentation. Most changes, considered individually, have been of a minor nature, but their introduction has been motivated by the over-riding requirement to give the Society a worthy and leading publication and to provide the best possible service to those who submit material to the Society for publication.

It may have been noticed, for example, that from January 1987 all articles have started in a right-hand page. This change was prompted by the decision to supply preprints (50 copies free-of-charge) to author(s) of each paper published. A further preprint service offered to authors also enables them to be supplied with copies in excess of 50 for a nominal charge.

Since April 1987, *JBIS* has carried the Society's Coat of Arms on a re-styled and more attractive front cover while the issue of October 1988 saw the introduction of colour printing, which can now be provided by special arrangement when there is an essential need for illustrations to be in colour.

JBIS Editorial Advisory Board

During 1988, the Society introduced a *JBIS* Editorial Advisory Board and revised and enlarged its Panel of Reviewers to strengthen the procedure by which submitted papers are processed and, if necessary, revised before acceptance for publication.

The composition of the Editorial Board is as follows:

PROF. P. BAINUM	Howard University
DR. B.I. EDELSON	The Johns Hopkins Foreign Policy Institute
DR. D.G. FEARN	Royal Aerospace Establishment
DR. M.J. FOWLER	Space Biomedicine Consultant
CAPT. R.F. FREITAG	Space Consultant
DR. R.D. GOULD	Royal Aerospace Establishment
PROF. G.V. GROVES	University of London
DR. R.M. HARDING	RAF Institute of Aviation Medicine
DR. R. HOLDAWAY	Rutherford Appleton Laboratory
PROF. D. HOWE	College of Aeronautics, Cranfield Institute of Technology
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PROF. I.E. SMITH	School of Mechanical Engineering, Cranfield Institute of Technology
DR. G. WHITCOMB	Future Science Projects, European Space Agency

JBIS has a current world-wide distribution of 2,000 copies per monthly issue to BIS members and subscribers, including many technical libraries.

***JBIS* Special Issues**

A well-known and much appreciated feature of *JBIS* is the coverage given to a special topic or subject area, such as space technology or space science, in special issues. Readers of ***Spaceflight*** who do not have a regular subscription to *JBIS* may like to know details of issues which relate to their own particular interests. Those for which there has been considerable demand in recent years hace been on Soviet Astronautics and Interstellar Studies. Stocks available of some *JBIS* issues from last year are detailed in the *JIBS* advertisement. Copies can be supplied post free at the prices stated on sending the appropriate remittance to the Society's Office.

Professor K.A. Pounds

We welcome to the *JBIS* Editorial Advisory Board Prof. Ken Pounds of the X-ray Astronomy Group, Department of Physics, University of Leicester who writes, 'I am delighted to accept your invitation to join the Editorial Advisory Board and look forward to helping to maintain the high standard of your Journal'.

Prof. Pound's contributions to Space Science have also been recognised by his election as a Member of the International Academy of Astronautics, which prompted us to invite him to update details about his career in the space

field and the work of the Leicester Group. He has written, saying:

My research career is contemporary, in a sense, with the space era in that I started out as a graduate student at UCL working with Dr (now Sir) Robert Boyd on a project to probe the Earth's ionosphere. My own part was to develop X-ray and Ultra Violet sensors which were flown on a series of Skylark rockets to measure the controlling solar flux. I moved to Leicester in 1960 to establish a new group to study solar physics within the department of Professor Stewardson. Throughout the 60's the Leicester Group continued to collaborate closely with the group at UCL in a series of rocket and satellite experiments including ARIEL 1, ESRO-2 and the NASA OSO-4 and 5 spacecraft. Highlights during this time were some of the first X-ray images and spectra of the solar corona.

Following the discovery of Sco-X1 in 1962 we were keen to move into this exciting new field and flew our first cosmic X-ray experiments at Woomera in 1967. From that time until the mid 1970's the Leicester Group carried out a series of Skylark experiments which were largely responsible for the first surveys of the Southern sky, the Northern sky being well covered by our US counterparts.

ARIEL 5, launched in 1974, moved our cosmic X-ray studies into the satellite arena and I believe the success of this mission is well documented. Our primary involvement was on the Sky Survey Instrument which made many discoveries, including several bright X-ray novae and the establishment of X-rays as a common property of active galaxies. ARIEL 6 followed in 1969 but this was much less productive scientifically because of a variety of technical problems, the most serious of which was interference by Soviet radars on the satellite command system.

The next major space mission for us was EXOSAT in which the Leicester Group was responsible for the design of one of the main instruments. We also have a much earlier connection with this first ESA X-ray Astronomy mission dating back to its original conception in 1970 and my own presentation of the mission to ESRO (as it then was in 1973). The science impact of EXOSAT is also well documented and resulted for a time in the centre of activity in this field of space science moving to Europe. Most recently we have been involved with the Institute of Space and Astronautical Science in Tokyo, a collaboration in which we jointly built the main X-ray detectors and are now sharing the operation and scientific analysis of the GINGA satellite. The significance of GINGA is underlined by it being currently the only operational X-ray mission worldwide.

Finally, looking to the future, we are now eagerly anticipating the launch of ROSAT in 1990 and JET-X three years later. My own role is as PI for the UK Wide Field Camera on ROSAT, which as you know is being produced by a Consortium of UK University groups, and as Project Scientist for JET-X. This latter instrument, which will form a major part of the Soviet Spectrum-X mission, is being developed by a consortium in the UK, Italy and Germany.

Work undertaken by Prof. Pound's X-ray Astronomy Group on the ROSAT Wide Field Camera is the subject of two papers published by the Society in the August 1988 issue of *JBIS*.

Fire Causes Delay

A major fire at the premises of the company who undertake the overseas dispatch of ***Spaceflight*** destroyed a number of copies. We apologise for any delay in the receipt of the March issue by overseas subscribers which may result and have made arrangements for additional copies to be printed and dispatched as quickly as possible.

Obituary

Kenneth J. Staples

We regret to record the death of Kenneth James Staples, a Fellow of the Society for over 30 years and a former aerodynamicist at the Royal Aircraft Establishment at Farnborough.

Joint International Conferences

The following conferences are being cosponsored by the Society:

The 8th Annual 1989 International

Space Development Conference

May 26-29, 1989

Themes will be Apollo: 20 years later. An Overview of Space. Space Technology, Business and Space. Meet Space Leaders, etc, etc. To be held at the Hyatt Regency O'Hare Hotel, Chicago USA.

International Conference on Space Power

Organised under the auspices of the IAF Space Power Committee.

June 5-7, 1989

To be hosted by Lewis Research Center in Cleveland, Ohio, USA.

Towards the International Space Station and Columbus

Hosted by the DGLR Hamburg, W. Germany.
October 4-6, 1989

Further details of the above meetings can be obtained from the Executive Secretary. Please enclose a SAE.

40th IAF Congress

The 40th Congress of the International Astronautical Federation (IAF) will be held at Beijing, China on October 7 to 13, 1989.

Members of the Society wishing to present papers may obtain procedural details for submission of abstracts from: The International Astronautical Federation, 3-5 Rue Mario-Nikis, 75015 Paris, France.

Future IAF Congresses are to be held at the following venues:

1990 Dresden (GDR) 6-12 October
1991 Ottawa (Canada) 5-12 October
1992 Washington, DC (USA) 27 August-5 September
1993 Ljubjana (Yugoslavia)
1994 Haifa (Israel)

SPACE '90

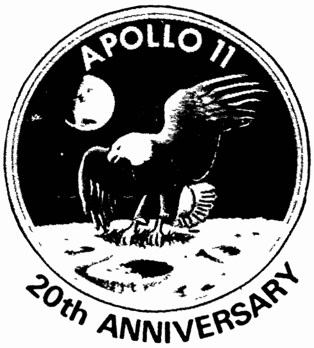
Members attending SPACE '38 and previous SPACE meetings asked that information on plans for future SPACE meetings be made available as soon as possible.

We are, therefore, pleased to announce that SPACE '90 will be held at the White Rock Theatre, Hastings on October 5th-7th, 1990. The theme will be 'Steps to Space'.

A full programme and other details will be available in due course. In the meantime the Society invites offers of papers, generally of 20-30 minutes duration, for consideration by the Organising Committee.

-MEETINGS DIARY

Special Event



To commemorate the 20th anniversary of the historic Apollo 11 lunar landing, the British Interplanetary Society has organised a series of lectures to celebrate Man's first steps on the Moon, concluding with a dinner at the Society's Headquarters.

Details of the meetings follow:

21 June 7.30-8.30pm

'I WAS THERE'

Reg Turnill and Frank Miles recall the atmosphere and events of twenty years ago. Reg Turnill was reporting from the US during Apollo 11, while Frank Miles was a member of ITN's "Space Unit" covering the mission from London.

28 June 7.30-8.30pm

LEGACY OF APOLLO

A lecture by Douglas Arnold illustrated by striking photography of Man's first steps on the Moon.

5 July 7.30-8.15pm

GOING TO THE MOON

Dr. R.C. Parkinson considers the BIS contributions to manned lunar concepts. Beginning with its design for a Moonship in 1939, the BIS continued thinking about ways of reaching the Moon throughout the 1950s. This talk illustrates some of the concepts, which culminated in the US Apollo programme.

19 July 7.00-8.30pm

INSTRUMENTATION ON THE MOON

Keith Wright talks about his work on the Apollo lunar surface experiments, in particular the 'Moonquake' instruments.

21 July 8.00pm

APOLLO ANNIVERSARY DINNER

The Society will conclude its Apollo 11 celebrations with a four course meal on the anniversary of Man's first steps on the Moon. (Guests of honour will be announced later).

All events will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members. Subject to space being available members may also apply for a ticket for one guest. Please apply to the Executive Secretary, enclosing a SAE.

Admission to lectures is free. Apollo Anniversary Dinner tickets are £28.

Symposia

3 June 1989 10am-4.30pm Symposium

SOVIET ASTRONAUTICS

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary

Registration

Admission is by ticket only Members should apply in good time enclosing a stamped addressed envelope

27 September 1989 9.30am-4.30pm

BRITISH SOLID PROPELLANT ROCKETRY

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

The emphasis will be on British post-war solid propellants and the development of associated rocket motors and launch vehicles.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary. Please enclose a SAE.

General Lectures

5 April 1989 7.00-8.30 p.m.

THE PROSPECTS FOR SPACE TOURISM

This lecture by David Ashford, will propose that Europe should develop a small fully reusable aeroplane-like launcher, as an alternative to Hermes, which could actually cost less to develop It could lead to a space tourism industry starting this century and developing into a large, if not the largest commercial issue of space

Admission is by ticket only Members should apply in good time enclosing a stamped addressed envelope

3 May 1989 7.00-8.30pm

UK INVOLVEMENT IN SATELLITE NAVIGATION

Dr. I.L. Jones

The UK has a long tradition of innovation and excellence in navigation based on our background as a trading nation. The UK has been particularly active in the application of the new techniques of satellite navigation. The presentation will describe the evolution of satellite navigation, highlighting the important scientific and commercial contributions of the UK to systems such as Transit and Navstar.

Finally, what does the future hold in this most exciting of fields?

Admission is by ticket only. Members should apply in good time enclosing a SAE.

Visit

13 May 1989, 10.30 am

UKAEA CULHAM LABORATORY

A tour of the United Kingdom Atomic Energy Authority's Culham Laboratory which is concerned with nuclear fusion and plasma physics research, and is the home of the Joint European Torus (JET) Project The tour will include the Control and Assembly Rooms

Admission is by registration only Members should apply before 15 April enclosing a stamped addressed envelope

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

Payload Specialist Flight Hopes

A new crewing policy in the United States may cause a number of payload specialists who were in training at the time of the Challenger accident on January 28, 1986 to lose their seat on the Space Shuttle. The following article provides a summary of those payload specialists and others who may still get a chance to fly.

The November 1985 Space Shuttle Payload Manifest showed a number of payload specialists from the sponsoring country or organisation. The resulting changes are outlined below.

STS 62-H

Since Palapa B3 was transferred to an Expendable Launch Vehicle (ELV), it is doubtful whether an Indonesian will now fly on the US shuttle. The seat was occupied by Pratiwi Sudarmono, who would have been the first non-Soviet, non-American woman in space. Born on July 31, 1952 in Bandung (Indonesia), she received an MD from the University of Indonesia in 1976, and a PhD in genetic engineering from the Research Institute of Microbial Diseases, Osaka University in Japan. A resident of Jakarta, Sudarmono is married and has a son, born in 1977. Her back up was Taufik Akbar, an engineer working for Perumtel, the Indonesian telecommunications corporation. He was born in Medan (Indonesia) in January, 1951.

STS 62-A

This was to be the first flight from Vandenberg Air Force Base in California: a DoD mission carrying the AFP-888/Teal Ruby satellite built by Rockwell International. Since the launch has been postponed for several years the spacecraft has been placed in storage.

Two payload specialists were scheduled for this flight. The first was John Brett Watterson, an Air Force Major and a member of the Manned Space Flight Engineer (MSE) cadre (see ***Spaceflight***, January 1989, p.26). Born in Garden City, New York, in 1949, he graduated from the Virginia Military Institute in Lexington with a Bachelor of Science degree in physics in 1971. He was selected for the MSE programme in February 1980. His back up was Captain Randy Odle.

By Bert Vis

The second payload specialist was to have been Edward C. Aldridge, an Air Force Under-Secretary at the time of his selection. He would have been the third politician to go up in space after Jake Garn (STS 51-D) and Bill Nelson (STS 61-C).

Aldridge was appointed Secretary of the Air Force and will not now ride the shuttle.

STS 61-I

Two payload specialists were also due to fly on this mission. One would have been the first journalist in space, whose selection was postponed indefinitely after the list of candidates had been narrowed to 40 on May 14, 1986. The other seat was reserved for an Indian payload specialist representing the ISRO (Indian Space Research Organisation).

Two Indian candidates had been selected and were in Houston at the time of the 51-L accident, although no final decision had been made regarding who would actually accompany the INSAT 1C satellite into orbit. INSAT was transferred to Europe's Ariane and was successfully launched on July 21, 1988 on Ariane flight 24. It is doubtful whether either of the two candidates, Nagapathi C. Bhat and P Radhakrishnan (P not being an initial but the first letter of his father's name, Paramaswaran), will make it into space via the shuttle.

Bhat was born on January, 1, 1948 in Sirsi (North Kanara) India. He graduated from Karnatka University in 1970 (BE Mech.) and the Indian Institute in Bangalore in 1972 (BEM/C Design). After working for Jyoti Ltd in Baroda from August 1972 to June 1973, he joined ISRO in July and started work at the ISRO Satellite Centre in Bangalore. He was worked on various Indian satellites like ARYABHATA, BHASKARA, APPLE and IRS. Bhat is married and has a son and a daughter. P Radhakrishnan was born on October 2, 1943 in Trivandrum, Kerala State in India. He holds a BS in Physics and Mathematics from the University College in Trivandrum (1963) and a MS in Physics from the same university (1965). He joined ISRO in April 1966 as a trainee and became a regular employee at what is now known as the Badram Sarabhai Space Centre in Trivandrum in September 1967, where he participated in the ARYABHATA, ROHINI, APPLE and INSAT projects. From January 1977 until February 1981, he was a member of the Programme Planning and Evaluation Group of theBakram Sarabhai Space Cente. In March, he became Head of the Test and Evaluation Division of the Systems Reliability Group. At present he is the Group Director of the Electronics group. Radhakrishnan is married and has a daughter and a son.

STS 61-L

The second Hughes Company payload specialist was scheduled to fly on this mission, with Syncom IV-5 as part of its payload. The new policy of not flying payload specialists unless they are of crucial importance to the mission will probably cost Konrad his seat. On the other hand, there is the possibility he may get the chance to perform the experiments that Greg Jarvis was to have carried out on STS 51-L, although no plans for a flight exist at this time.

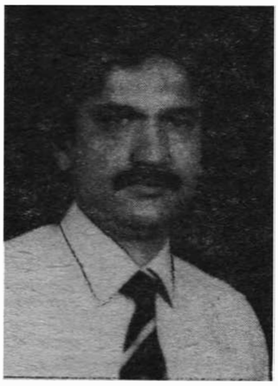
STS 71-C

Two non-NASA satellites were planned for launch from Columbia's payload bay during this flight: ASC-2 for the American Satellite Company and Skynet 4B of the British Ministry of Defence - both were rescheduled for launch by ELVs.

The ASC payload specialist's name had not been submitted to NASA by

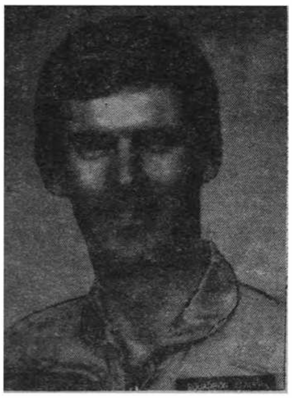
Pratiwi Sudarmono

Nagapathi C. Bhat

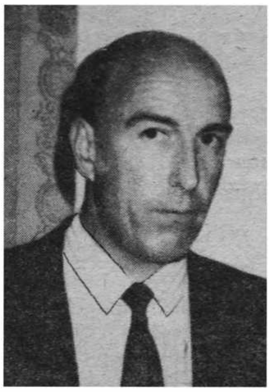


P Radhakrishnan

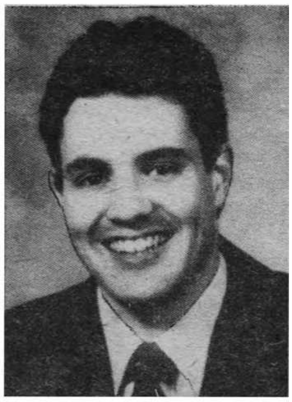
Edward C. Aldridge



Nigel R. Wood



Peter H. Longhurst



Robert J. Wood

Otto W. Hoering

January 1986, as the company was still in the selection process, although one candidate, Otto W. Hoering Jr. had been provisionally chosen in November 1985. Hoering was born on July 21, 1938 in Kansas City, Missouri. In 1960, he received a BS in Mechanical Engineering from the Texas A&M University. Prior to joining ASC, in June 1984, he worked as an independent satellite communications consultant to industry and government. Since February 1987, Hoernig, who is married and has two children, has been Vice-President, Business Development with Contel ASC.

The UK's second payload specialist Cdr. Peter Longhurst, is also unlikely to fly especially following the MoD decision to reschedule Skynet 4B to Ariane.

Other Missions

A number of people that were already assigned to missions can still be fairly certain they will make their flight and these include scientists, selected as payload specialists for scientific missions, who have a vital role in carrying out the experiments.

Although such flights are facing considerable delays, specific knowledge of instruments and fields of research will make a strong case for Lampton and Lichtenberg (STS 61-K), Nordsieck and a second ASTRO-3 payload specialist (STS 71-M), a Japanese scientist on STS 81-G and Hughes-Fulford on STS 81-M. Durrance and Prise, originally scheduled for STS 61-E, the mission that was to fly after 51-L, have been recently assigned as payload specialists for STS-35.

Also, Bob Wood, of McDonnell-Douglas, will probably get his chance: the complexity and importance of the EOS (Electrophoresis Operations in Space) programme requires skilled personnel to accompany the equipment aboard the Shuttle. A test device was operated by McDonnell-Douglas engineer Charles Walker on missions 41-D, 51-D and 61-B.

Some candidates may be helped by politics: the fact that Nigel Wood would be Britain's first astronaut could be of help to him and Canadian Steve MacLean may fly if Canada remains a partner in the Space Station programme. MacLean was due to operate the Space Vision System on 71-F. This system is designed to increase the accuracy of the Remote Manipulator System and docking operations.

Uncertain is what will happen on DoD missions. The MSE fell victim to a steadily declining interest from the Air Force, and most of the 32 members of the group were transferred or have resigned from the military. Only two of them Craig Puz and Maureen LaComb, are officially assigned to a shuttle mission: the Starlab defence spacelab flight. Their back-ups have not been announced. In June 1988 however, Puz and LaComb were involved in an automobile accident in Boston, in which both were injured. It is to be seen if and how this will affect their assignment.

Another military payload specialist candidate is Major Carol Belt, a meteorolgist of the Air Weather Service. Belt was born on January 30, 1953 in Red Oak, Iowa. She is single. Her back-up is Major Lloyd Anderson (36).

Conclusion

The only real conclusion that can be made is that none of the candidates that were scheduled for a flight can be 100 per cent sure of getting the seat he or she was to occupy prior to the Challenger tragedy, except maybe for Durrance and Parise, the payload specialists in the only crew (61-E) that was not disbanded shortly after the accident.

NASA's decision not to fly payload specialists on the first five missions currently has no influence on this as Astro-1 is scheduled for the eleventh flight designated STS-35.

Space Shuttle manifest for November 1985 showed a large number of missions carrying payload specialists

Mission	Launch	Prime	Back-up
61-E	Mar 6, 1986	Samuel T. Durrance Ronald E. Parise	Kenneth N. Nordsieck
61-H	June 24, 1986	Pratiwi Sudarmono Nigel R. Wood	Taufik Akbar Richard A Farrimond
62-A	July 1986	J. Brett Watterson Edward C. Aldridge	Randy T. Odle
61-J	Sept 27, 1986	Nagapathi C. Bhat or Journalist-in-Space	P. Radhakrishnan Journalist-in-Space B/U PS
61-K	Oct 27, 1986	Michael L. Lampton Byron K. Lichtenberg	Dirk D. Frimout Charles R. Chappell
61-L	Nov 6, 1986	John H. Konrad	Stephen L. Cunningham
71-A	Jan 12,1987	Kenneth H. Nordsieck ASTRO-1PS	(1)
71-C	Jan 27, 1987	Peter H. Longhurst Otto W. Hoernig	Christopher J. Holmes ASC B/U PS
71-D	Feb 16, 1987	Robert J. Wood	Charles D. Walker
71-E	Mar 16, 1987	Francis A. Gaffney Robert W. Phillips	????? ?????
71-F	Mar 24, 1987	Steven G. MacLean	Bjarni V. Tryggvason
71-M	Aug 18,1987	Kenneth H. Nordsieck ASTRO-3PS	(1)
81-G	Feb 23, 1988	Spacelab J PS (2)	Spacelab J B/U PS
81-M	July 20, 1988	Millie Hughes-Fulford SLS-1 PS (3)	?????

Notes to Table

1 The Astro payload specialist team consisted of three members, all of whom were to make two flight and serve as back up on the third This means that the back up for STS 61-E, Kenneth H Nordsieck, would fly on STS 71-A and 71-M, while both Ronald E Parise and Samuel T Durrance would be back up on one mission.

2 Three scientists were selected as candidates for this mission Takao Doi, Mamoru Mohn and a woman, Chiaki Naito One of these three would fly while another would be back up

3 A second payload specialist was to be selected "shortly" when the flight assignments for Gaffney, Philips and Hughes-Fulford were announced on April 24, 1985 At the same time of the Challenger accident he or she still had to be named however

CORRESPONDENCE

Space Shuttle

Will NASA again save Solar-Max?

Sir, Now that the euphoria over the return of the Space Shuttle has died down following the flights of Discovery and Atlantis perhaps it's a good time for NASA to review America's future in Space.

However, I am disturbed to hear NASA is forgetting about the present. It has now in orbit amongst other spacecraft America's only functional Solar/Meterological observatory. Called Solar-Max it provides the West with its only source of combined solar and atmospheric data: it studies solar flares thus giving us a better understanding on how the Sun works and how it affects medium-term global weather phenomena. It even studies the 'ozone' layer! . . . And its going to 'reenter' the Earth's atmosphere and be destroyed in little under 13 months time.

Is NASA going to unwittingly kill this valuable national-asset-in-space just like it did the Skylab 9 years ago? All that would be needed to effect a rescue is a meagre $25m and one quarter of the cargo-bay of a Space Shuttle to carry the necessary equipment to re-boost its orbit. Or would they rather save $25m and see one $250m spacecraft be destroyed in the process? We'll soon see which way they'll decide; for Solar Max comes back for good in 1990, in a burning shower of debris.

RAMON HARTOPP
Barcelona, Spain

Ed. There is little hope that a 1989 rescue mission can be mounted on account of the already tight shuttle schedule. (See ***Spaceflight***, March 1989, p.85)

Payload Specialists

Sir, Recent developments in astronaut flight assignments for NASA space shuttle missions have helped to clarify the question of whether non-astronaut 'passengers' will be permitted to fly on the shuttle in the foreseeable future. On January 11, 1989 the National Research Council of Canada announced that the second solo flight of a Canadian Payload Specialist on the shuttle has been delayed one year to 1992. Canadian physicist Steven MacLean is scheduled to conduct experiments with the Space Vision Systems (SVS), designed to provide the basis of 'artificial vision' for automated remote manipulator systems for the planned Freedom Space Station. The first Canadian shuttle payload specialist, Marc Garneau, flew aboard the shuttle Challenger on mission 41-G in October 1984.

The day following the announcements at NASA Headquarters in Washington, the space agency announced that except for scientist-astronauts aboard Spacelab missions and a limited number of Payload Specialist opportunities such as the Canadian astronaut flight in 1992, non-astronauts (such as school teacher Christa McAuliffe who perished in the Challenger accident) will no longer be permitted to make shuttle flights. By way of provid ng an 'escape clause' for the sternly worded policy, NASA announced that exceptions could be made in cases where flying a certain passenger would 'contribute to their approved NASA objectives or to be in the national interest.'

Additionally the National Research Council of Canada announced two payload specialist candidates for the International Microgravity Laboratory (IML) Spacelab flight, currently scheduled for launch in February 1991. The two Canadian astronaut candidates are Dr. Roberta Bondar, a 43 year old neurologist, and Ken Money, 54, internationally recognised as an expert on weightlessness and human physiology. A decision will be made in 1990 as to which researcher will actually make the flight. The European flight candidates have yet to be announced for IML-1.

J.W. POWELL
Calgary, Alberta, Canada

Ed. For a review of the effect that the Challenger accident had on the future plans and flight opportunities of Payload Specialists see p.134.

External Tank

Sir, The space shuttle's vast external tank, if only it was delivered to orbit, could become its unique asset.

The planned space stations with their pretty modules must be crammed with kit to be cost-effective, but at a price. They lack workspace. In time the lack will be felt of a "Tank Farm" to provide repair bays, storage, life-boat hangars, waste-holding, stability, strong-points for mooring and/or boost, and rare recreational volume. Also, shielding.

N. KELLY
Liverpool, UK

Space Station Resupply

Sir, Although the Freedom Space Station (FSS) will need the Space Shuttle to set it up, there are arguments in favour of smaller shuttle craft to assist in routine resupply and crew rotation etc.

Instead of about three Shuttle resupply missions per year, the FSS could be visited every four to six weeks by a mixture of Shuttle and Hermes craft. This would have the following advantages:

(1) The variation in routine by regular visits would improve morale on the FSS. There would be more opportunity to see new faces, get fresh food, letters etc. The crew would also feel less isolated.
(2) Crew members could be rotated one or two at a time rather than in bulk providing continuity, ie at any time there would only be one or two crew members finding their 'space legs'. This may also reduce clashes in personality caused by long periods in close proximity.
(3) The existence of two independent supply systems would improve safety.
(4) A failure of equipment or crew illness on the FSS is less likely to present a major problem when on average a resupply flight will only be two or three weeks away.
(5) New materials and the results of experiments etc would be returned to Earth more frequently for analysis and this would speed up feedback to the FSS.
(6) A missed, delayed or re-scheduled flight is less likely to be critical.
(7) Provision of logistics would be far easier because it would not be necessary to predict all FSS needs three or four months in advance. (Just how many Mars bars will eight crew members consume in four months?)

I wonder if NASA may have been better joining the ESA in developing Hermes than spending money on a replacement for the Challenger orbiter. Regrettably, whatever the practicalities of such a mixed shuttle fleet, one must be realistic and conclude that the possibility of the US putting money into a European inspired venture in favour of its own space program is somewhat remote.

PETER R. HALL
Bucks, UK

Soviet Space Programme

Keen interest in Soviet space activity is reflected in correspondence to Spaceflight

Energia Payload

Sir, As far as payload capabilities are concerned, the launch mass of a fully-loaded Energia by Soviet statements can be 2,400 tonnes but if you measure the launch accelerations from both the Energia 1 and the Eenergia 2/Buran missions you derive a launch mass of 2,400 tonnes from the known sea level engine thrusts. My own figures indicate the fully laden Energia with four strap-on boosters can loft just over 150 tonnes to the point which the shuttle orbiters separate: this implies a payload to low Earth orbit of about 140 tonnes after subtracting the orbital injection propellant and kick stage. Clearly Buran will never use the fully laden Energia and the Energia-1 was carrying a less-than-maximum payload mass.

PHILLIP CLARK
Lee, London SE13

Energia Dimensions

Sir, Mr Lawton's letter in ***Spaceflight***, November 1988, p.438 about the Energia engines is highly relevant. The vehicle would seem better called Enigma.

The basic question is the dimensions. The initial "about 60 metres height" and 8 metres for the core diameter can hardly be simultaneously correct, in view of of the aspect ratio as seen in pre-launch photographs, these being genuine although taken on the slant and with partially obstructed sightlines.

Other less reliable, but more accessible, representations reconcile these dimensions but include a suspiciously long engine section. Mr Lawton's suggestion removes a few metres from the engine length of Energia as launched. This is what is needed, for if the 8 metres is correct the height is about 56 metres, not 60, and the latter is a hardly justifiable approximation.

The interest of the dimensions is the light they shed on the size and capabilities of Energia, and this might seem to have been resolved anyway by the Chief Designer's *Pravda* article (***Spaceflight*** October 1988, p.381). But this is not the case.

The basic factors determining the capabilities of a vertically-launched rocket are the take-off thrust and the propulsive technology. The Chief Designer parades before us a vehicle surpassing Saturn V in these respects. Yet the culminating achievement of a quarter of a century of technical advance is, apparently, to reduce the low earth orbit payload by more than 30 per cent. Perhaps yet another alternative name for Energia would be Economia, symbolising the economy with the truth.

TONY DEVEREUX
Essex, UK

Piggy-Back into Orbit

Sir, The recent introduction of the Antonov An-225 six engined transport aircraft has opened new horizons to the future of Soviet Space Transportation Systems (STS). With a payload of 250 tons carried inside the fuselage or piggyback on top, it has been officially stated that the aircraft is to transport parts of the Energia and Buran type orbiters. This heavy payload capability will make it an ideal platform for fully reusable STS. Two basic configurations can be proposed:

1. A HOTOL type spaceplane with an air breathing rocket engine using less demanding and sophisticated technologies, having an overall mass of over 200 tons. Note that Bernard Carr proposed to get the HOTOL on a jumbo jet modified for this purpose [1]. The jumbo here was working well above its designed payload levels and was criticized by J.C.E. Moore [2]. In fact even Mr Moore's 200 ton payload limit for a jumbo jet is optimistic. The latest version '747-400' with an extended wing and uprated engines took off at a record breaking weight of about 405 tons (gross wt.) compared with 600 tons for the An-225. The floor loading on the fuselage is an important factor in determining the maximum payload carried by an aircraft, so one cannot simply add its internal cargo load together with a large portion of fuel carried mostly in the wings to assume a maximum carriable payload on top of an aircraft. This is one reason why the Lockheed C5B is used in the USA as a strategic air lift aircraft with a maximum designed payload inside the fuselage of about 120 tons. A typical B 747 will not do any better. This is the main difference between a dedicated cargo aircraft and a passenger aircraft of the same size. One can exceed the designed internal payload at the expense of fuel by an amount not exceeding 20-30%. As an example to this, the An 124 has a designed max. cargo of 150 tons giving a range of 4,500km. It has been certified in a record breaking mission to carry 188 tons. The same applied to earlier smaller aircraft. Taking this into consideration we find that the British HOTOL with an overall mass of 230 tons can fit neatly on top of an An-225 with no modifications to the aircraft basic design, since it already possesses a widespan twin tail very similar to the one proposed by Mr. Carr on his modified B 747. The internal fuel available will give it a cross range for launching the HOTOL of over 2,000km from where it took off. This will be very useful for different inclination missions, giving it flexibility and no danger of cross winds.

It remains to be seen whether the Soviets will be capable of building a HOTOL type spaceplane of their own.

2. A Teledyne Brown Engineering spaceplane type [3] but scaled up to a factor of around two to give a total mass around 250 tons, and LEO payload of around 10 tons.

Note that a lot of the Soviet launches still use the A-2 launcher after 30 years of reliable operation in its different versions, showing no signs of phasing out. By the turn of the century there will still be a need for a launch vehicle in the ≤10 ton category capable of replacing the A-2 and maybe even the Cyclone launchers, used at a rate of once weekly, mainly for LEO missions both manned and reconnaissance. Fully reusable systems should provide the solution. Later on the Proton booster could be phased out in favour of SL-16 launcher for both GEO and planetary missions, leaving the Energia and the shuttle orbiters for heavy space station construction and assembly. There will still be a need for a small expendable launcher in the C-1 category accomplishing the remaining missions.

M.Q. HASSAN
Baghdad, Iraq

References.
1 ***Spaceflight*** March 1987, p.90
2 ***Spaceflight*** May 1987, p 207
3. ***Spaceflight*** December 1987, p 413

Ed. *Readers may be interested in the following Tass statement issued on December 12, 1988:*

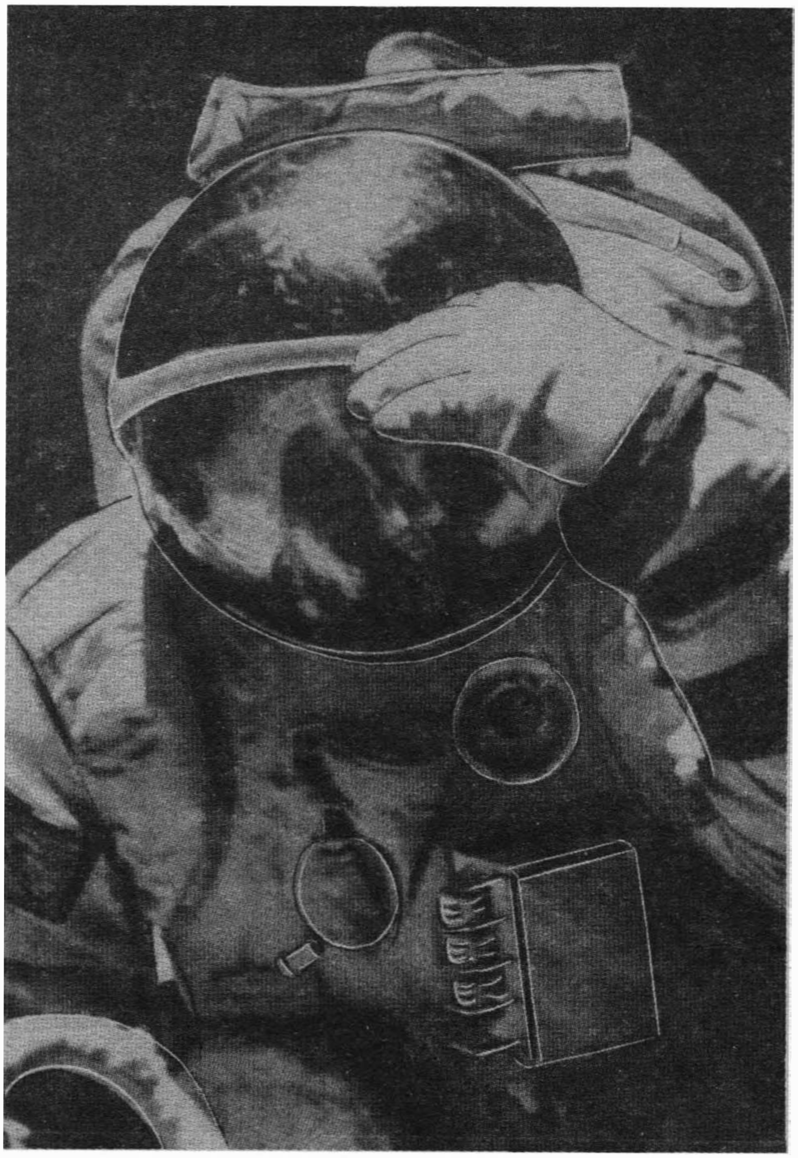
'Academician Struminskiy believes that the future belongs to aircraft-type vehicles different from both the shuttle and Buran — aerospace craft costing between two and five times less that the present systems. It would be a modification of the hypersonic passenger aircraft now under development in the USSR and elsewhere; prototype engines using hydrogen were tested in the Tu-155 airliner in April. Cryogenic hydrogen could be used to improve the dynamic characteristics of the wing by cooling its surface'.

(138)

Above the Planet

Salyut EVA Operations

Regular *Spaceflight* correspondent *Neville Kidger* continues his review of spacewalks made from the Soviet Union's Salyut series of space stations.



Kizim gives a salute during a space walk from Salyut 7.

1984: A Banner Year

On September 9, 1983 the Salyut 7 station suffered an oxidiser pipe leak which was first reported in the west and which the Soviets originally did not acknowledge.

As the Soviets later admitted, the leak was potentially serious. "A blow-out of oxidiser could take place (from two oxidiser tanks) into the unpressurised assembly module," a report on the incident said in 1987.

After an initial concern for the cosmonauts' safety (Lyakhov and Aleksandrov were aboard Salyut 7 at the time) it was determined that the flight could continue. In order to determine the specific area of the leak gas was pumped from a Progress cargo ship through the oxidiser pipelines.

The area of the leak was established and the probable cause determined, but the problem still troubled engineers. It was decided that the next crew would effect a full restoration of the Combined Engine Installation (Soviet acronym ODU) to gain "the capability and technological experiences in conducting operations in outer space". Salyut 7 had been operating normally on account of the branching dynamic pressure design of the ODU.

The next Salyut crew would have three members - Leonid Kizim, Vladimir Solvyov and Dr. Oleg Atkov. The first two were to conduct a number of EVAs to by-pass and seal the leaking pipe.

More than thirty different tools were developed for the operation including special ladders and cutting tools, wrenches, hydraulic crosspieces for by-passing the unsealed area and a tool container and waste carrier, according to Solvyov. About 90 per cent of these tools were declared inventions by the Soviets.

The cosmonauts practiced the activities on mock-ups of the system on an IL-76 aircraft flying a parabolic trajectory to create weightlessness, and used test bench models. Training was also done in the Star Town hydro tank. All-in-all the men held about 30 EVA training sessions involving almost two hundred contingency situations.

In addition, the men were also scheduled to make an EVA to erect the second pair of DSB solar panels.

Kizim, Solovyov and Atkov were launched in Soyuz T-10 on February 8 1984. They docked with Salyut one day later and, for seven days in April, played hosts to the Soviet/Indian visiting flight before commencing their work outside.

[illegible]

Four Times Outside:
April 23 to May 4 1984

Prof. Konstatin Feoktistov notes, after the end of the 1984 flight, that many variants of the work needed to be accomplished with the ODU had been developed the most unlikely one requiring six EVAs to fulfil the programme. This was precisely what happened. Progress 20 was docked for the first 4 EVAs. It had a special platform attached to it for the cosmonauts to stand on. At 0431 GMT on April 23 Kizim and Solovyov opened the EVA hatch. Atkov was inside Salyut's working compartment monitoring medical parameters).

The first EVA was dedicated to the installation of a 5 m ladder and the arrangement of the working site, according to Solovyov. "Then with the help of a piercer and special cutter we succeeded in opening the plastic hatch cover, behind which in an unpressurised container were the hydraulic connections of the propulsion system," wrote Solvyov.

The package of tools, with a weight of

about 40 kg, was attached to the work area. The two men returned to Salyut, closing the EVA hatch after an EVA lasting 4 hours 15 minutes.

The second EVA began at 0240 GMT on April 26. After 20 minutes of clambering along the ladder to the work area the men made holes in the station's outer skin over the area of the ODU's reserve conduit. There the men installed a valve. The conduit was blown through and its airtightness checked. However, at one stage a stubborn nut, covered with epoxy putty, refused to budge. The men used a special wrench to undo the nut, but that cost them about two hours of the scheduled 4 hours and 5 minutes allotted to this EVA.

Kizim and Solovyov asked for permission to carry on with the work but flight controller Valeri Ryumin told them to return to Salyut saying "we realise that you're enjoying [the work], but soon enough you'll have the opportunity to get on with the job again and carry it through. So don't rush it, or you'll deprive yourselves of that satisfaction."

The hatch was closed on the second EVA for Kizim and Solovyov after 4 hours and 56 minutes (reported by Tass as 5 hours).

Original plans called for two EVAs in April, according to Soviet sources. (The EVAs were planned for early morning Moscow Time for daylight coverage. Tracking ships in the Atlantic and Pacific ensured up to 50 minutes of contact with the men per orbit.) The men asked for, and received, permission to conduct a third EVA in April.

At 0135 GMT on April 29 the hatch opened again. Once at the work site they connected two filler tubes with a metal bypass line. This added a new conduit to the main reserve. Nitrogen was blown through the pipe to ensure that it was airtight. The thermal covering was reinstalled over the work area to ensure the correct thermal conditions. They packed away their tools and returned to Salyut after an EVA lasting 2 hours and 45 minutes. Kizim and Solvyov were the first Soviets to make three EVAs on a single flight.

At 2315 GMT on May 3 the men opened Salyut's hatch yet again and made their way to the work site. Solvyov later wrote that each time they made their way to this site the men had to pull bulky containers with equipment and tools in them. "During the first EVAs this route was not easy for us and gave us a lot of trouble. We had to stop very often and sometimes return to free the tether or take the tools or TV camera out of an undesirable position," Solvyov said. "Experience was gained after the second and third EVAs and we got the hang of doing it and passed our route 'almost running'."

During this EVA the men removed the thermal blanket again and installed a second extra conduit, checking its airtightness after installation. It was only now, according to Solovyov, that using "a very original logic based on the commands from the ground and the pressure checks by the propulsion system control panels that the unsealed point was finally located. This was performed by cosmonaut Atkov who was inside Salyut 7 at that moment."

The thermal blanket was replaced and the men returned into Salyut after an EVA of 2 hours 45 minutes.

Svetlana Savistskaya.

New Solar Panels: May 18 1984

Progress 20, which had been used extensively during the first 4 EVAs of the tenure of Kizim, Solovyov and Atkov departed on May 6 to be replaced four days later by Progress 21.

This cargo ship brought the second set of DSB additional solar panels. The new set contained solar cells made from gallium-arsenide which would give 6 amps more power than the existing silicon cells.

At 1752 GMT on May 18 the hatch opened again and Kizim and Solovyov exited. The men carried out tool boxes and two containers with the folded DSB's in them. The men soon winched up the first panel.

Atkov, inside Salyut, then commanded the array to rotate 180 degrees so that the other side faced the cosmonauts outside. At one stage of the operation the winch handle broke, giving rise to concern by the previous crew to complete such a task - Lyakhov and Aleksandrov - about microsatellites flying off. The two containers become microsatellites when the cosmonauts in orbit cast them off into space.

Solovyov then began attaching the electrical cables to connect the DSBs to the main panel. The flight engineer "puffed and panted" as he struggled to tie two knots in the bundles of wire in a repeat of problems encountered by the previous crew. "Like trying to thread a needle in boxing gloves," Aleksandrov told a reporter.

With both panels installed and connected the men returned to Salyut's interior and closed the hatch on a three hour five minute EVA. Their record now stood at five EVAs for a total time outside of 17 hours 50 minutes.

A Woman Walks in Space: July 25 1984

Although it was unkown in the west, the four EVAs of Kizim and Solvyov had not completed the repair of the Salyut oxidiser line. Soviet planners scheduled yet another foray to the site of the leak to seal off the leaking pipe entirely.

Procedures were developed and tools built and tested for this purpose. The Soviets also trained a ground-based cosmonaut, Vladimir Dzhanibekov, in the operation and initially proposed that he would perform the work outside the station. Kizim and Solvyov objected to this so a plan was devised where Dzhanibekov would fly to Salyut and train the men in orbit with a model of the clamping device and show videotapes of the operation as Dzhanibeko had practiced it in the Star Town hydrolab.

It is unclear when the next addition to Dzhanibekov's mission was made - the first walk in space by a woman.

The Americans had assigned Kathryn Sullivan to Shuttle Mission 41-G in November 1983, that flight was to include an EVA by her and a male crew-member. Also on the flight would be Sally Ride, America's first woman in space, who would be making her second trip into space. The Soviets, never ones to allow the Americans to set a space first without a try themselves, planned to achieve both those records by flying Svetlana Savitskaya, who made her first flight in 1982 to Salyut 7.

Savitskaya was also to perform an EVA to test out a multipurpose welding, cutting, soldiering and spraying tool (Soviet acroynum URI) in open space. The device was developed by the Paton Institute in Kiev where automated tools, called Vulkan and Ispaatel had been developed and tested in Soviet spacecraft from 1969. URI's purpose was to replace the automated tools with a manual tool.

The heart of the tool, two electron beam guns, was housed in a container along with a step-up transformer and a high-voltage rectifier. A voltage convertor, which stepped up low-voltage direct current from the spacecraft to 5-6 kV alternating current for the URI, was housed separately. The gun and its accessories - an airtight electronics box, a control unit, fixing handles, etc, were housed in a single container.

The weight of URI was less than 3 kg and the mass of the entire package was 30 kg without the holder for the samples. The power source was the heaviest element.

The Soviets say that URI took some time to be included in the mission. Physicians, were yet to overcome the psychological barrier." Until the very last moment reservations were voiced about using the tool."

URI was tested in a pressure chamber where experimenters gained proficiency with it over three sessions and in an aircraft flying a parabolic trajectory.

Soyuz T-12, carrying Dzhanibekov, Savitskaya and Igor Volk (included at the request of the Ministry of Aviation Industry as part of his preparation for flying the Soviet shuttle) was launched on July 17, 1984 and docked with Salyut 7's rear port the next day.

The EVA was scheduled for the seventh day of the flight. With six cosmonauts aboard Salyut provision was made for an emergency return to Earth should there be a problem with the EVA. Whilst Dzhanibekov and Savitskaya were on EVA Solovyov was sealed into Soyuz T-11 at the front of the station. If an emergency occured, the two spacewalkers would enter T-11 and return to Earth. Kizim, Atkov and Volk were located inside Salyut's working compartment.

In the afternoon of July 25 the cosmonauts assumed their positions and at 1455 GMT the hatch of the station was opened for the sixth time of the 1984 occupation.

Dzhanibekov was first outside. He stepped onto the Yakor platform and secured himself. The Yakor had been folded for two years. A sample container was removed for return to Earth and a lamp set up.

The URI, and its associated test boards, was handed out by Savitskaya and plugged into an external power outlet. The task took slightly longer than planned but, as the complex passed over Africa, Svetlana Savitskaya floated out of the hatch.

The first woman to conduct an EVA at first caught her tether and complained that "the sunlight is blinding my eyes." Dzhanibekov advised caution. Once on the Yakor Savitskaya rested.

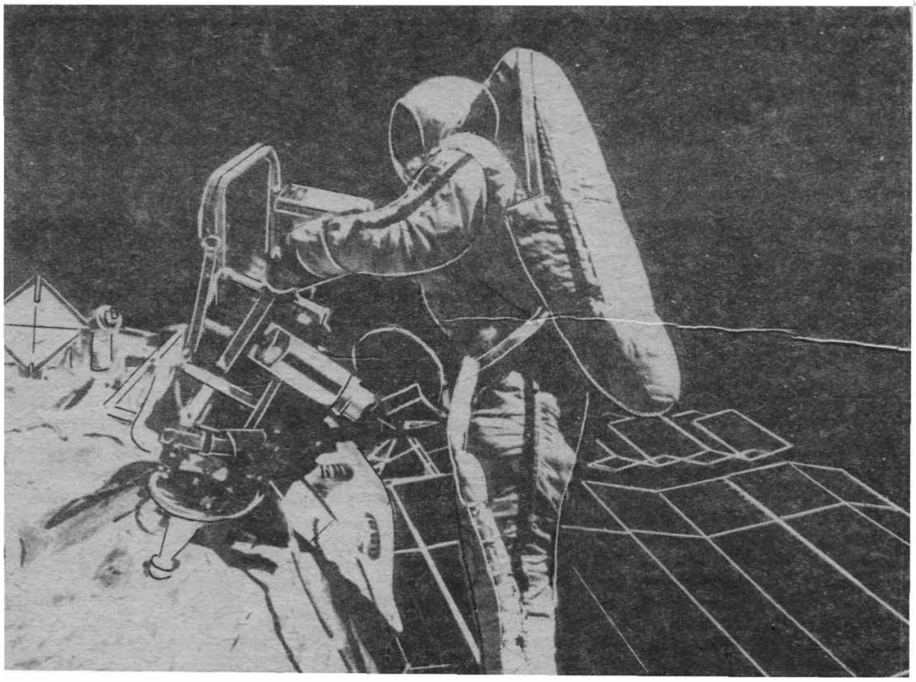
Dzhanibekov, now back in the hatchway, set up a TV camera. Direct contact was established with FCC. Flight controller Valeri Ryumin asked for a status report.

"Can we start?" Savitskaya asked. "Well, if you're so impatient, then start it," was the reply.

"I have begun the work. I have switched on the instrument. We have power," Savitskaya reported. The first task involved cutting a 0.5mm thick sample of titanium. It took less than one minute to make a 10 cm cut.

Turning to another set of pre-cut samples she began to weld them together. The samples were 1 mm thick. At first the weld did not give a very even result, Savitskaya reported. She later reported that she had achieved "three tack welds and the seam is good."

TV pictures showed her flipping the four sample boards up and down as she continued the tests of the URI. Six welding experiments were conducted - two samples of titanium and four of stainless steel, She conducted six cutting experiments - three of titanium and three of stainless steel. Six soldering experiments involving tin and lead were conducted and, using the second electron emitter, fitted to a special crucible, melted solder and sprayed it onto anodised aluminium discs. The crucible took 45 seconds to heat the solder. There was concern that the work would not be done before nighttime.



Svetlana Savitskaya during her 3 hour 35 minute EVA, on July 25, 1984. She became the first woman to walk in space and the first woman to make two space flights.

Kizim was asked how the world's first woman spacewalker was doing: "Sveta is working fine," was his reply from inside Salyut, Atkov told Savitskaya that a dinner had already been prepared for the celebration of the EVA. However, she replied that she was not returning until the work was done.

Before the complex entered darkness Savitskaya reported to FCC that the cutting and welding experiments appeared good but that she was having difficulty seeing the solder and the spraying results, the Sun had hindered her.

Savitskaya, responding to a question from FCC said that although not cold her right leg was slightly numb.

As the complex passed through orbital nighttime the two spacewalkers swapped positions. Savitskaya described what she could see:

"Earth is beautiful not only when lit up by the Sun but also when in the shadow .. I was overwhelmed by the fantastic spectacle of thunderstorms with brilliant flashes and play of colours against the black background of the clouds. These light phenomena seem to remind us that there are still many enigmas in nature. Meanwhile, in areas not hidden by clouds, the lights of lots of cities and towns could be seen. Looking from outer space, it is obvious that the Earth is an inhabited place and that there is intelligent life on it."

When contact was resumed with FCC, after a 40 minute break, Dzhanibekov was operating the URI. Speaking about the spraying operation, the veteran cosmonaut said that it was "like painting a wall ... the tool is very handy and I am sure we'll be using it a lot."

When Dzhanibekov finished the URI tasks he put the electron gun back into the container, closed the plate holders, fixed them and handed the whole assembly to Savitskaya in the hatchway.

Before returning into Salyut's compartment the two placed a container with bio-polymers on the outside of Salyut. This was a continuation of the Medusa experiment and was designed to non-biogenetically synthesise the components of nucleic acids in open space. Other cassettes were removed and placed inside Salyut.

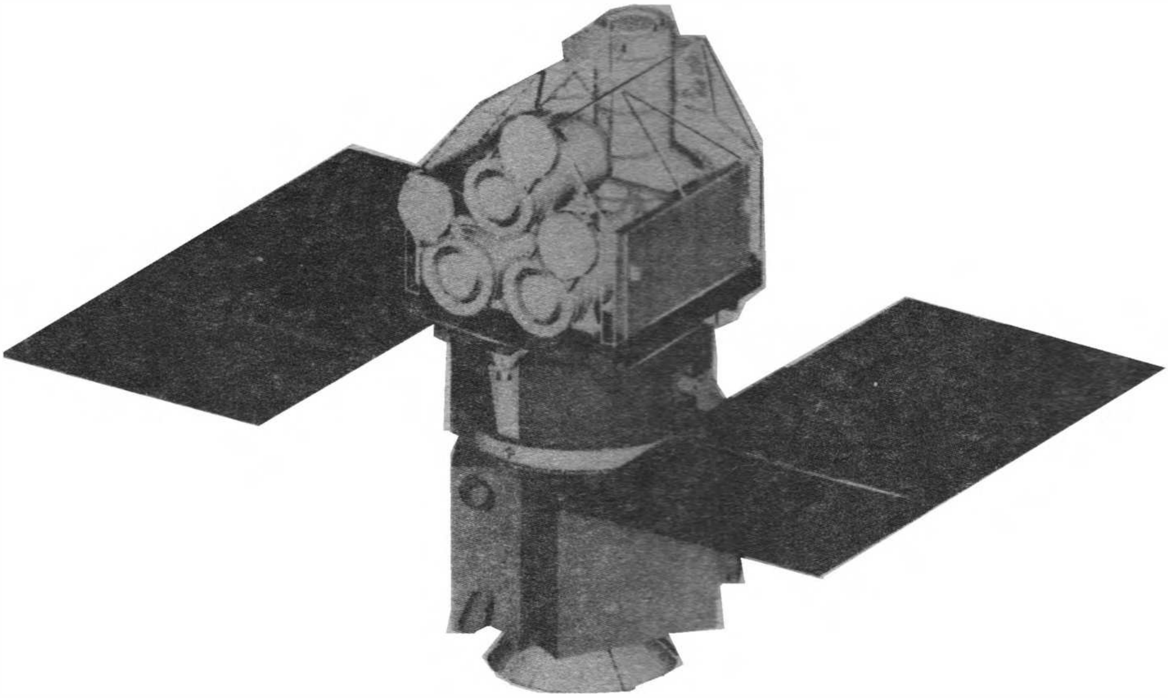
The hatch was closed on the EVA after being opened for 3 hours 35 minutes. Inside the station, as the cosmonauts waited to doff their spacesuits, Dzhanibekov beamed TV pictures of Savitskaya to FCC. She gave a heartfelt thanks to the makers and testers of URI in the Ukraine.

On October 5 1984 Sally Ride and Kathryn Sullivan were launched as members of the seven-strong Shuttle 41-G crew. Ride became the first American woman to make two flights and, later in the flight, Sullivan made her EVA with David Leestma. But by then both records were held by Savitskaya.

In 1988 Georgi Grechko told a reporter that Savitskaya had found herself in trouble during the EVA "and had to be rescued " He said that women were "no good" in space and that they should stay on Earth!

This major feature on Soviet EVA operations continues in the next edition of *Spaceflight*.


SPACE SHUTTLE FLIES AGAIN
ASSEMBLY
THE CREW
TESTING
TRAINING



Making Space News
in New Zealand

The resumption of shuttle launchings with mission STS-26 on September 29, 1988 did not go unnoticed in New Zealand thanks to the special efforts of *David Maclennan*, Fellow of the BIS and Vice-President of the New Zealand Spaceflight Association, who writes about his 'STS-26 Awareness Program'.

The STS-26 Awareness Program really began only two weeks before launch, when I learned of the launch date itself. The work involved displays, newspaper features, lectures and radio features, and until I had this firm date I could not do much about organising sites for displays, for example.

To assist the news media I prepared a media kit on the mission based on the NASA one. As the NASA one did not arrive until less than a week before launch, the media had this kit only a couple of days before launch. Despite the lateness, it was well appreciated, as far as I can tell. Earlier in the month I had sent out a news release altering the media dto the fact that the launch was near, and that it would be a newsworthy event.

I took a weeks leave from work to prepare the displays and organise other aspects of the Awareness Program. There were two displays: the one in the photo opposite, which was in a bank window downtown, and a larger display on the shuttle programme as a whole was part of a 'Space Shuttle Day' held at the local Planetarium the day after launch. The latter also continuously-screening Shuttle mission videos.

I wrote two feature articles on the Shuttle recovery programme and STS-26, which were published in two of the country's major dailies, the Evening Post and the New Zealand Herald.

Of the various news media here, radio was by far the most responsive. I was interviewed on air several times in the weeks leading up to the flight and during the mission itself. I also persuaded the national radio network here to broadcast the Voice of America commentary on the launch, though I could not talk Television New Zealand into covering the launch live (TVNZ virtually ignored the flight together). In the hours leading up to the launch the national radio network also broadcast NASA "Space Story" tapes on STS-26 that I had supplied.

Although coverage of the mission here was not as good as it could have been, I feel the STS-26 Awareness Program did at least ensure that more New Zealanders were aware of what was going on than might otherwise have been the case. From my point of view I was pleased that despite the shortness of time, everything planned got done.

And of course, the most gratifying thing of all is that the mission was a success! I only wish I could have gone to the Cape to see the launch in person.

(Top) A display on the shuttle programme mounted in the window of a high street bank in Wellington, New Zealand as part of the STS-26 Awareness Program.

(Bottom) The Explorer Platform with solar panels extended and the EUVE payload module consisting of three identical 'Scanning' Telescopes plus the Deep Survey/ Spectrometer (see diagrams in p.144).

Satellite Telescopes
Extreme Ultra Violet Explorer (EUVE) Mission

EUVE is a new project to be launched by NASA in the summer of 1991. The satellite will map the entire sky in the extreme ultraviolet band of the spectrum, something which has not yet been attempted. Under development since 1979, EUVE is expected to find a whole array of new sources in space, from new stars to quasars and white dwarfs.

Dr. Roger Malina, **a Fellow of the BIS, is a member of the project's Science Team and Principal Investigator of the EUVE Instrument Development Project. He now provides *Spaceflight* readers with an insight into some of the novel features of this mission.**

Introduction

The Space Astrophysics Group (SAG) at the University of California, Berkeley is an organization devoted to the expansion of scientific discovery and research. Employing over 100 people, the group is responsible for several projects in collaboration with NASA and other research groups and universities. Through the direction of Professor Stuart Bowyer, SAG has been a leader in the study of the extreme and far ultraviolet bands of the spectrum; new, high-efficiency detectors and spectrometers; research on the interstellar medium; the search for extraterrestrial intelligence; and ground-based observations of high energy sources.

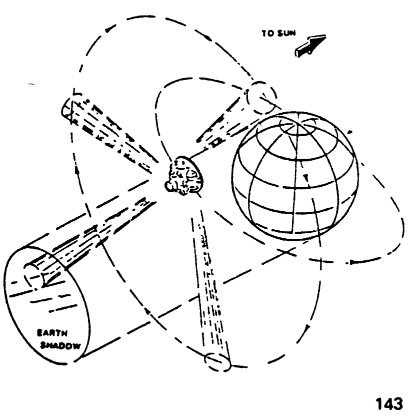
The Extreme Ultraviolet Explorer

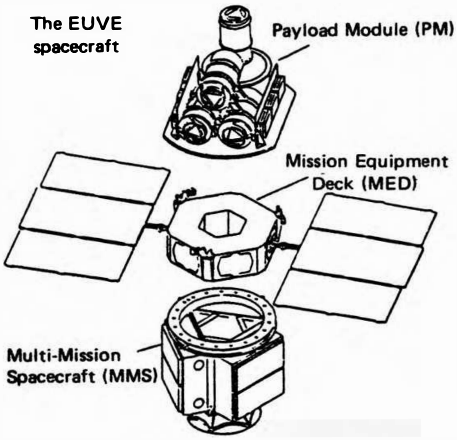
The Extreme Ultraviolet Explorer (EUVE) will be launched by a Delta 2 expendable launch vehicle and attached to a multi-mission spacecraft (MMS) similar to that used for the Solar Maximum Mission. After completion of the EUVE mission, the shuttle will be used to retrieve the EUVE science payload and install a second science user. The MMS Explorer platform itself will remain in orbit for 15 years.

The EUVE satellite will be placed in a circular orbit at an altitude of 550 kilometers. Mapping of the extreme ultraviolet will occur through the spin motion of the MMS, which uses the Sun as its orientation point. At the end of this six-month "sky survey" phase, the scanning telescopes will have viewed the entire sky. Meanwhile, the deep survey/spectrometer will be viewing in the anti-Sun direction, carrying out a deep survey of the sky located along the ecliptic. During the second six-month spectroscopy phase, the spectrometer will be pointed at selected stars.

The science payload of the EUVE satellite will consist of three identical scanning telescopes and a deep survey/ spectrometer. Each of these instruments will be equipped with a telescope interface (TIF), and all four TIFs will be interfaced to a common command data and power electronics unit. The four instruments thus will interface to the spacecraft as a single payload.

EUVE Orbit.





The EUVE spacecraft

Historical Note

The first non-solar EUV source was discovered using a SAG telescope on the Apollo-Soyuz Mission in 1975. Previous enthusiasm for this part of the electromagnetic spectrum was dampened by the realization that there was a reasonably dense interstellar medium and, absorption coefficients being about as high as they can get at these wavelengths, it would be almost opaque.

In 1974 calculations indicated that direct observations of stars in the EUV should be possible out to about 100 pc. These stars would have to have a surface temperature in excess of 20,000 K and would have to lie on a line of sight in a direction where the neutral hydrogen density was very low. During the early 1970's, many people were reporting measurements indicating that in certain directions, neutral hydrogen densities could be as low as 0.01 cm^3.

Apollo-Soyuz offered the opportunity to make extended observations and 20 hours of observational time was logged. On the seventh day of the mission, July 22, 1975 at 22h 26m, the spacecraft was rolled to a target in Coma Berenices. Over the instrument horizon something came into view, and with it, a new field of astronomy. Subsequent raster scans confirmed that the countrate was reproducible and that the source was localized to a region centered at RA 13h 14.0m and Dec +29d 22m. At that position exists the hot white dwarf known as HZ43.

Back on Earth, the analysis of the data obtained through different filters gave a crude estimate of spectral energy density. A simple blackbody fit enabled the extraction of the following information regarding both the nature of this new type of star and the interstellar medium. The surface temperature of the star could be as high as 110,000 K (compared to our Sun's 5000 K), and this would mean its radius is about 7800 km (compared to the Earth's 8000 km). The density of the interstellar medium (in that direction) would be 0.014 cm^3.

Having proved that observations to distances well beyond 300 light years were feasible, the Berkeley group headed by Prof. Bowyer (SAG) realized that over 100,000 stars could be found in that volume, many of which could be expected to be bright at EUV wavelengths. A survey of this volume of space would provide fundamental new information about the local stellar population, energy transport in stellar atmospheres, and the ionization and opacity of the interstellar medium.

Confirmation was provided by a number of new rocket payloads, which were launched in rapid succession as thesis projects by Webster Cash (November 1976), Roger Malina (November 1978), Randy Kimble (June 1982) and Pat Jelinsky (November 1983). The flight of the "Blue Rainbow" by Roger Malina in April 1978 obtained the first spectrum of HZ43, indeed of any stellar EUV source, and reported the discovery of helium in the photosphere of the white dwarf.

With a speed which can only be described as awesome, by December 1976 the group had prepared for submission to NASA a 300 page proposal which gave a detailed description for an Extreme Ultraviolet Explorer.

EUVE Spectrometer

The six-month phase following the All-Sky Survey by the EUVE Scanners will be dedicated to spectroscopy of the brightest sources newly-discovered by the Survey. The EUVE Spectrometer to be used for this task will have a novel slitless design incorporating variable line space (VLS) gratings which correct for the fact that the light from the mirror is converging.

The Spectrometer will have three wavelength channels, each of which will use one-sixth of the Wolter-Schwarzscild II telescope aperture. The remaining half of the beam will be focussed onto the Deep Survey Detector, which will perform a long-exposure survey of a portion of the sky along the ecliptic and in the direction of the spectroscopy targets.

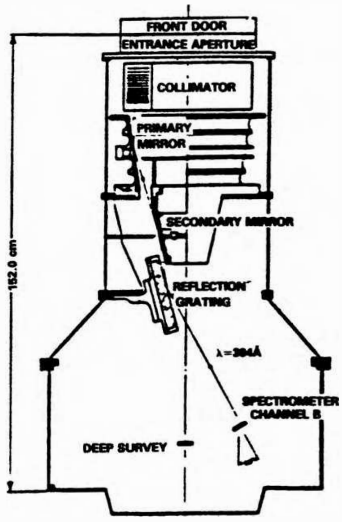


Diagram of the Deep Survey/Spectrometer Telescope which has a Wolter-Schwarzschild Type II mirror. The ray path is traced for channel B which is sensitive to HeII 304Å line emission.

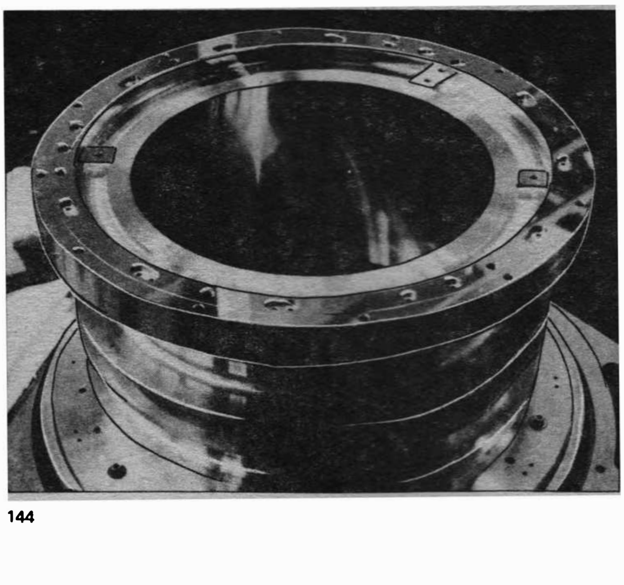
Roger F. Malina

Roger Malina graduated from the Massachusetts Institute of Technology in 1972 with a B.S. degree in Physics and a year later embarked on a career in astronomy at the Space Sciences Laboratory, University of California, Berkeley, undertaking research on UV and X-ray emissions from astronomical sources and gaining his Ph.D degree in 1979. The following year he was appointed Associate Research Astronomer at Berkeley and has since played a leading part in the EUVE mission acting as Principal Investigator for EUVE Science Instruments.

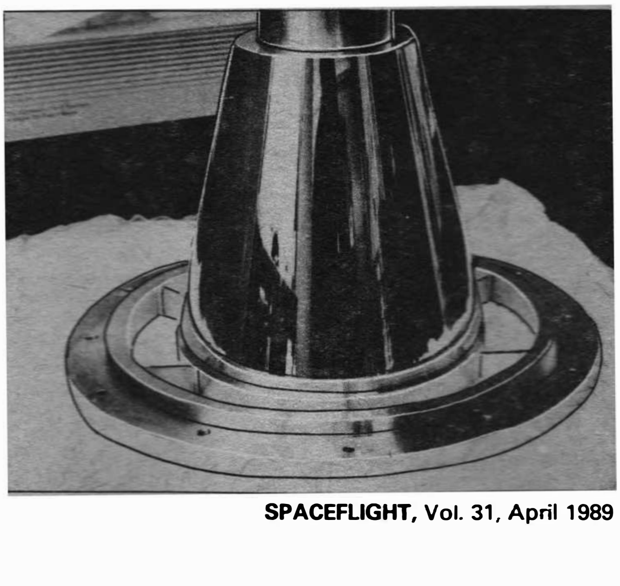
Roger Malina was elected to the British Interplanetary Society in 1976 and maintains a close interest in the Society's activities. In 1988, he was joint author of a technical paper on the EUVE mission which was published by the Society [1].

[1] S. Bowyer, R.F. Malina and H.L. Marshall, 'The Extreme Ultraviolet Explorer Mission: Instrumentation and Science Goals', *JBIS*, 41, p.357-361 (1988).

Primary Mirror of Spectrometer.



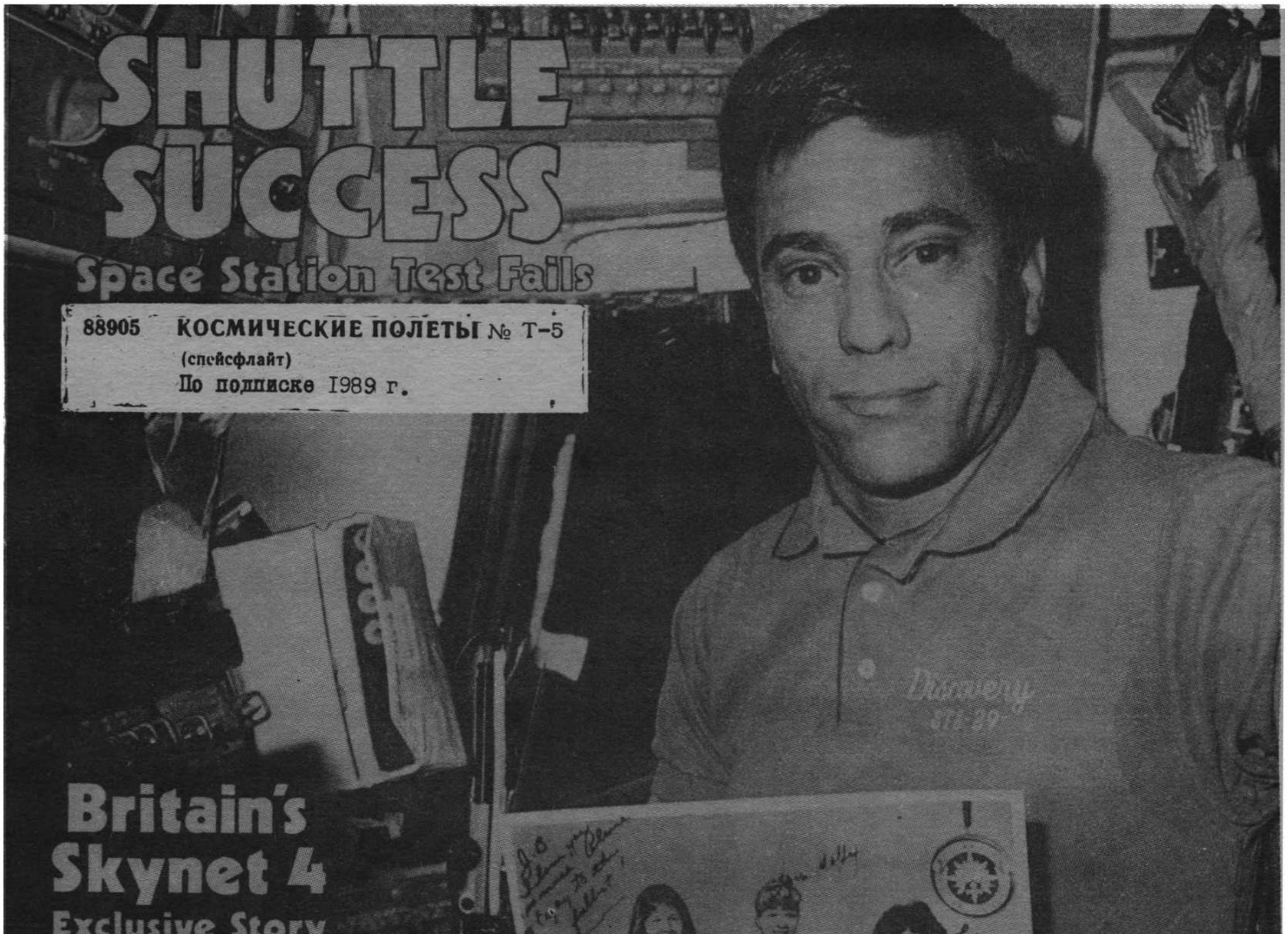
Secondary Mirror of Spectrometer.



May 1989 US $3.25 £1.25

Spaceflight

The International Magazine of Space and Astronautics



Spaceflight
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DISTRIBUTION DETAILS

Spaceflight may be received world-wide by mail through membership of the British Interplanetary Society. Details from the above address. Library subscription details are also available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by Magnum Distribution Ltd., Cloister Court, 22–26 Farringdon Lane, London EC1R 3AU. Tel: 01–253 3135.

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Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published monthly by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L., Ltd., Aylesbury, Buckinghamshire, England.

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Vol.31 No.5 **May**

Front cover: Astronaut John Blaha holds up a picture of the STS-29 crew members' wives from the pilot's station on Discovery's flight deck The photo was sent up by the Text and Graphics System (TAGS) which made its inaugural flight on STS-29. *NASA*

Atlantis Poised for Launch

When the Space Shuttle Atlantis blasts off from pad 39-B at the Kennedy Space Center it will be carrying a precious cargo: NASA's first interplanetary probe since Voyager was launched 12 years, ago. By the end of the Magellan mission it is hoped the probe will have mapped over90 per cent of the surface of Venus. STS-30 is officially scheduled for launch on April 28, but a delay of four to five days seems inevitable.

The Crew

Atlantis will have a crew of five on this, her fourth flight. Mission commander, David Walker, is making his second space flight. He was the pilot of mission 51-A in November 1984. Pilot for STS-30 is Ronald Grabe, who was onboard Atlantis for her maiden flight, 51-J. The remaining crew members are mission specialists. Norman Thagard, a medical doctor, is a veteran of two shuttle missions, STS-7 and STS 51-B. Mary Cleave, will be the first woman to fly the shuttle since the Challenger accident. Women astronauts return to space after a break of over three years. Infact Cleave herself was the last woman in orbit when she flew on shuttle mission 61-B in November 1985. The only 'rookie' member of the crew is Mark Lee who joined NASA as an astronaut in 1984.

Launch Preparations

Preparations for the launch of Atlantis were complicated by the damage to the spacecraft's tiles that occurred during her last mission. Once fully refurbished, Atlantis was rolled over from the Orbiter Processing Facility to the Vehicle Assembly Building (VAB) on March 12, where the orbiter was attached to the Solid Rocket Boosters and External Tank. During Atlantis' tow to the VAB the assembled members of the press got a closer look than they bargained for, reports *Spaceflight* correspondent David Portree. The portside wing passed over their heads allowing close inspection of the heat-shield tiles, before they were moved to another location by security men.

The Atlantis stack was slowly rolled down the 4.2 mile gravel crawler-way to the launch pad on the morning of March 22 reaching the pad at 8am local time. After electrical and mechanical connections between the vehicle and the pad were made, work began on the final launch preparations.

Like Discovery, Atlantis' main engines received a new set of high pressure oxidizer turbopumps. The first of the pumps was installed while the vehicle stood in the VAB, leaving two to be replaced on the pad. One of the final two pumps had to be returned to the Stennis Space Center for further testing and was not installed until early April.

The STS-30 crew were at the Kennedy Space Center for the Countdown Demonstration Test, which serves a dress rehearsal for the launch. On April 7 the crew boarded the orbiter as they would on launch day. The mock countdown continued until T-5 seconds, at which point the crew and ground staff had to deal with a simulated main engine shutdown. Following the test the STS-30 crew familarised themselves with the escape methods if a malfunction occurs on the pad.

Magellan

The Magellan probe must be launched between April 28 and May 23 to make its interplanetary window. Although the launch was still scheduled for April 28 at the time of going to press, a delay of four to five days was expected. If the probe misses the all important launch window, Earth and Venus will not be in the proper alignment again for two years.

A delay of four to five days will not be a serious threat to the mission, infact some Magellan scientists would like to see the probe launched later. If Magellan is boosted toward Venus on April 28 it will arrive slightly faster than optimal, so its attached Star 48-B solid rocket motor will be unable to brake it into the optimum 3.15 hour orbit for which the mission is designed. Magellan project scientist Dr. Stephen Saunders stated that a May 5 launch would serve better the scientific purposes of the Magellan mission by allowing it to achieve the proper orbit around Venus. However, NASA officials would prefer to see Atlantis lift off on schedule rather than take the risk of a last minute problem delaying the launch past May 23.

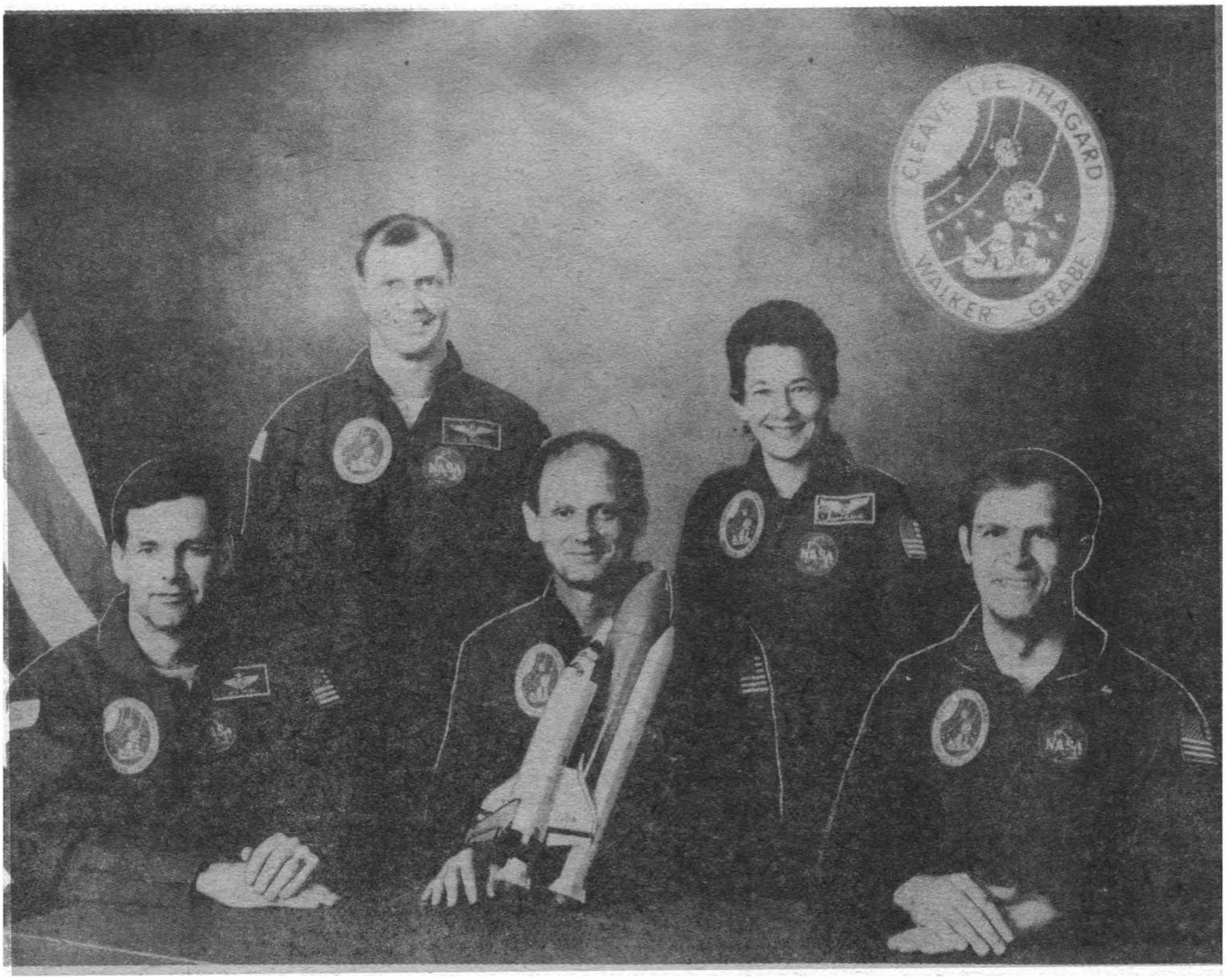
The Magellan probe will be boosted out of Earth orbit by an Inertial Upper Stage (IUS). The deployment sequence will be similar to that of the Tracking and Data Relay Satellite (the most recent TDRS launch was STS-29, see p.172 for a full report). All five crew members will be involved in the deployment of Magellan, although Mark Lee will have chief responsibility. The 3,500 kg spacecraft will be released from Atlantis' payload bay approximately six hours 18 minutes after lift-off. The IUS booster will fire about an hour later to start the probe on its 15-month journey to Venus. The spacecraft is due to arrive in August 1991.

Magellan is to map the planet continuously for 238 days, the length of one Venusian day. By the end of that period 90 per cent of the planet will be mapped. Scientists plan to extend the mission to fill the gaps in mapping coverage at that time, if additional funding for the project is approved.

The recent failures of Phobos 1 and 2 have raised concerns that a similar fate could befall Magellan. NASA officials have strongly denied their spacecraft could be lost in a similar way. John Gerheide, JPL's Magellan project manager told the press the "riskiest part of the Magellan mission would be the insertion into the orbit of Venus, but he appeared confident of the outcome. "It's a smart spacecraft," he said. "It can heal itself of any problems."

In addition to the satellite deploy, the STS-30 crew will perform several mid-deck experiments, including the Fluids Experiment Apparatus (FEA) and the Meoscale Lightning Experiment (MLE). The later involves nighttime photography of violent weather systems on Earth (should they occur during the mission) to learn more about lightning.

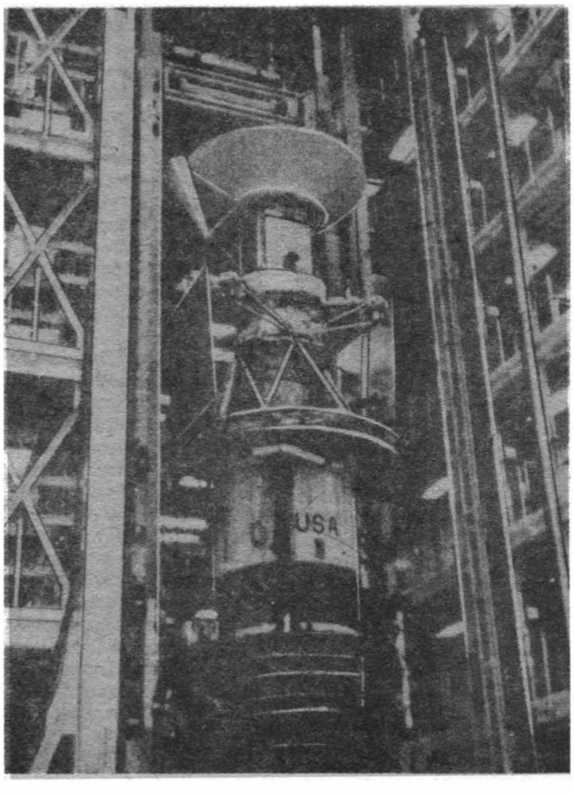
The Space Shuttle Atlantis is towed to the Vehicle Assembly Building before mating to the Solid Rocket Boosters and External Tank.



(Above) The STS-30 crew portrait. (Left to right) Pilot John Grabe, Commander David Walker, Mission Specialists Norman Thagard, Mary Cleave and Mark Lee. *NASA*

(Right) The Magellan probe and its Inertial Upper Stage Booster are prepared for transfer into Atlantis' payload bay. *D.Portree*

(Below) The Magellan mission emblem.



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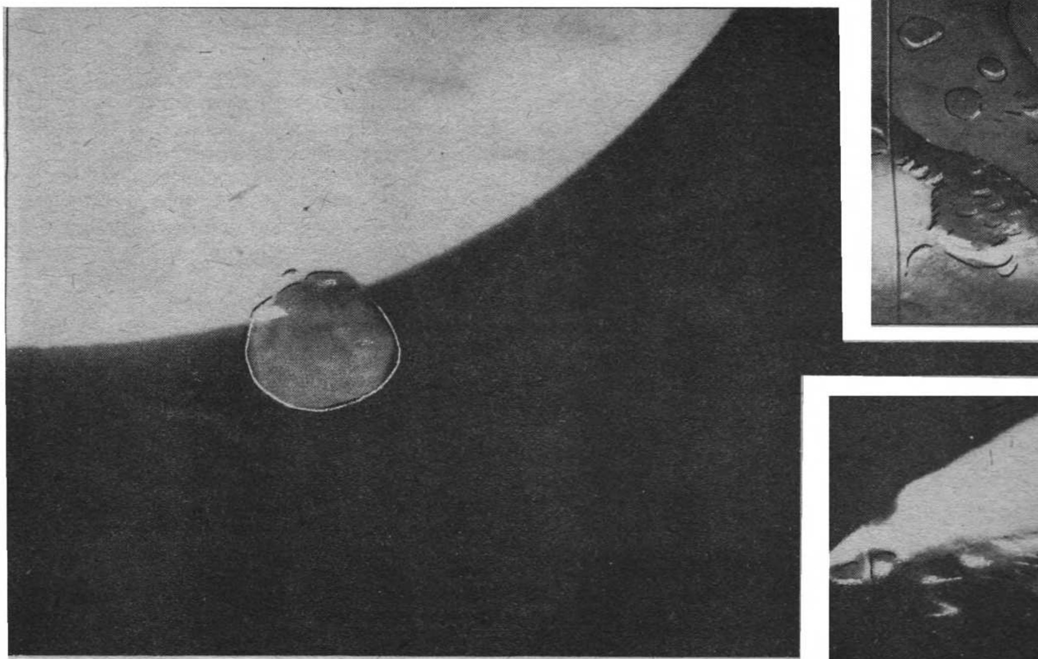
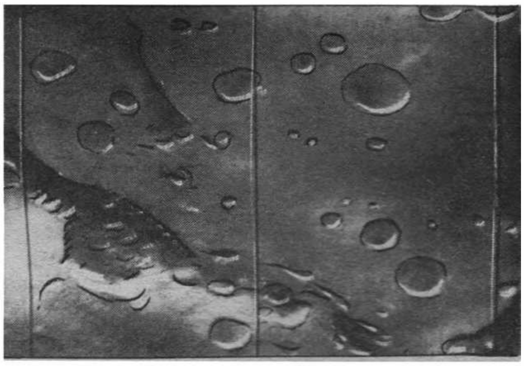
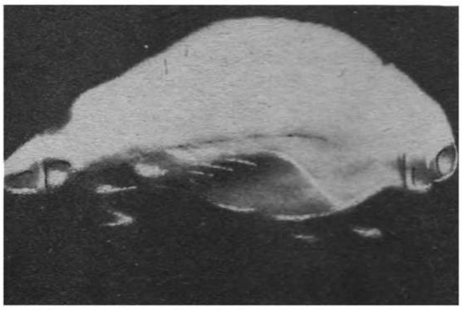






Before Phobos 2's untimely end, the probe transmitted many images of Mars and its largest moon. (Left) An image of Phobos seen against Mars. (Top right) A close up of Phobos. (Bottom right) Phobos 2's view of the surface of Mars. The pictures were taken from the television screen at the Mission Control Centre before any enhancement of the images. *Novosti*

Phobos 2 Falls Silent

By Neville Kidger

Soviet scientists at the Flight Control Centre near Moscow have lost contact with the unmanned Soviet probe to Mars and its moon Phobos. It ends the ambitious flight before the planned encounter with the moon upon which rode much scientific interest and Soviet prestige.

Controllers are unaware why the probe ceased radio contact with Earth on March 27, but theories range from a collision with the moon itself or an impact by a micrometeorite.

The probe had been turned towards Phobos to take further pictures of the moon to specify the parameters of its orbit. Soviet scientists were first alerted that all was not well when the probe failed to return the images. Attempts to recontact the probe have so far proved unsuccessful. Alexandr Dunayev, head of the Soviet space agency, Glavkosmos, is hoping "for a favourable outcome." But Western observers believe there is little chance of recontacting the probe.

The Soviets established a commission to determine why contact with Phobos 2 was lost. The commission was to report within a week. At the time of going to press its findings had not been made public.

According to John Pike, a member of the federation of American Scientists, who viewed the launch of Phobos 2 from Baikonur, the Soviets may have installed a "very stupid" computer on the probes with a view to saving weight. In an interview with *New Scientist* Pike said there had been a great deal of acrimony between the Institute of Space Research and the Babakin Bureau, which designed the craft, regarding the design of the Phobos probes. He speculates that in future the Soviets may design their probes in a more 'Western fashion' where the history of every component is documented thoroughly.

During the planned fly-by of Phobos the probe would have used laser and ion beams to discover the composition of the soil of Phobos and would have deposited two small landers onto its surface.

The first lander would have anchored itself to Phobos by means of a penetrator and lanyard to return TV pictures and other data. The second, weighing 50 kg would have used springs to "hop" around the surface in the low gravity of the moon.

Thirteen nations and organisations took part in the project with the USSR.

The Flight

Phobos 1 and Phobos 2 were launched from Baikonur by Proton rockets on July 7 and 12 respectively last year. They were placed into an interplanetary cruise phase shortly after reaching Earth orbit using an attached propulsion system.

In August the probes began relaying data back to Earth. On-board instruments returned X-ray and ultraviolet data on the Sun and the characteristics of interplanetary shock waves.

However, during a communications session scheduled for September 2 no signal was received from Phobos 1. An operator had sent an incorrect command which told the probe, in effect, to shut down. The probe's antenna lost its lock with Earth and the craft began tumbling, losing orientation with the Sun and causing the batteries to be depleted without being recharged.

Academician Roald Sagdeyev, then head of the Institute of Space Research in Moscow, described the loss of Phobos 1 as a "disastrous mistake". All hopes for the successful completion of the mission rested with Phobos 2.

In late December 1988 it was revealed that "isolated malfunctions" had occurred in some of Phobos 2's instruments. It was claimed that most of the faults had been corrected whilst others would not prevent the full research programme going ahead.

At 12:55 GMT on January 29 the propulsion system of Phobos 2 was ignited for 201 seconds to place the probe into Martian orbit after a journey of 470 million kilometres. A final correction to the approach path had been made six days earlier.

The Phobos 2's initial orbit was 79,750 km x 850 km; period 76.5 hours; inclination to the Martian equator 1 degree.

ESA reported that the probe reached the point of closest approach to Mars for the first time on February 1 at 18:39 GMT just 864 km above the surface. Science data stored on the probe's recorder was relayed to Earth at 12:00 GMT the next day during approach and around the first periapsis.

A series of engine firings, placed Phobos 2 into an almost circular orbit with an average radius of 9,670 km and an 8 hour period inclined at 0.5 degrees. This established the so-called observation orbit. At this point the propulsion system attached to the probe was discarded after being used six times during the flight. Smaller thrusters would be used for fine

Briton to Fly on Mir

The Soviet Union is to carry the first Briton into space under an agreement which was due to signed on April 14. The launch has been scheduled for 1991 and will last one to two weeks. During this time the British astronaut will carry out a number of scientific experiments onboard Mir.

British Astronaut Project Limited - a consortium of British companies - has been established to manage the venture. At the time of going to press the consortium was on the verge of signing the agreement with the Soviet space agency, Glavkosmos, and its commercial arm V/O Licensintorg.

The effort to launch the first Bntish astronaut will be a purely commercial one, with no Government funding. However the presence of UK Energy Secretary, Cecil Parkinson, at the signing ceremony in Moscow indicates strong Government approval for the project.

The cost to the British consortium will be in the region of $10 million, which is to be raised through various sponsorship deals.

The British astronaut is likely to be a scientist. He or she will need to be physically fit and able to speak fluent Russian. The training will take about a year and will cover emergency procedures and the basics of living onboard the Mir space station. A short list of five to ten candidates will be submitted to Glavkosmos by September. The space agency will then choose a prime candidate and a back-up, who will be trained for the flight at Star City near Moscow.

Meanwhile a Tokyo television company has paid for a Japanese journalist to spend a week aboard Mir. The Soviet press are said to be furious that the first journalist in space will not be a Russian.

Cosmonaut Grechko to Fly Again

Soviet cosmonaut Georgi Grechko, has revealed that he is to make a fourth space flight, writes ***Neville Kidger.***

Writing in "Moscow News" in an article unrelated to space he said that he had received permission for the flight from the physicians and his superiors, but not from his wife who, he said, has poor health "partly due to my flights."

The veteran cosmonaut did not say when the flight was scheduled but it can be surmised that he will be launched in late 1989.

Grechko is now an Earth scientist and his involvement may be due to the presence of Earth environmental monitoring equipment which is to be installed on the second Salyut-class module which will be launched to Mir later this year. Grechko's experience may be needed for the operation of the equipment. In this instance he would probably be partnered by a rookie commander.

It cannot be ruled out, however, that Grechko could make a short-term visiting flight to Mir rather than a six-month-long flight which is the current duration for the resident crews on Mir.

Phobos Continued

manoeuvres.

The orbit had a radius some 300 km greater than that of Phobos. For three days the probe's instruments made observations of Mars' atmosphere, surface and near-planet space.

The first of nine TV sessions devoted to Phobos occurred between 12:35 and 13:25 GMT on February 21 when the probe was at distances ranging from 860 to 1,130 km from the moon. Phobos was centred in the images, providing the Soviets said, evidence of the accuracy of the navigational and ballistics data. These computations had involved inputs from NASA and the European Space Agency, the Soviets acknowledged.

Real time relays of pictures were not possible and the pictures of the moon were later replayed from the tape recorder of Phobos 2.

During the evening of February 27 controllers adjusted the TV camera using Jupiter as the target. The axes of the probe were fixed to the Sun and the bright star Canopus. Having verified the orientation of the probe by this method, the cameras were swung to take more pictures of Phobos.

The probe continued to slowly close on the moon over the next weeks.

Commenting on the orbital measurements made by the navigational teams, the Soviets said that when the probes were launched the ephemerides of the moon were known to an accuracy of 100 to 150 km. By early March this had been refined to 10 to 30 km. The accuracy had to be down to just several kilometres for success.

By March 14 the probe and moon were just 100 km apart. The Soviets planned the hover phase to occur on April 9 or 10.

Contact with Phobos 2 was lost on March 27 and shortly afterwards Albert Galeyev, head of the Institute of Space Research, reported the mission's abrupt ending.

Results

Whilst the loss of the approach and hover phase of the Phobos mission is a serious blow to Soviet science and prestige, the Phobos 2 mission did manage to gather many images of Mars and Phobos and provide data on the Sun and Mars' environment which will keep some of the international group of scientists busy for months or years to come.

The probe may have discovered radiation belts surrounding Mars similar to the Earth's Van Allen belts.

The Future

The next Soviet Mars probe will be launched in 1994 and will feature studies of the planet itself using both orbiter and balloons dropped into the atmosphere. There were plans to send a lander and a rover during this mission but these plans have been dropped.

In addition, studies released in 1988 showed that the Soviets were looking at the possibility of using the Energia launcher to send a series of heavy vehicles to the planet. The studies showed that between 1994 - 1996 Mars would be studied with heavy unmanned vehicles including orbiters, balloons, rovers and drillers.

The years 2000 to 2005 would see the development and testing of future manned mission elements including nuclear electrical jets, Mars landers including sample return vehicles.

The Soviet plan gives the years 2005 to 2010 as those intended for the manned mission to Mars.

Debris Figures

NASA's Goddard Space Center has reported that on December 31, 1988 there were 7,119 objects in orbit. Of these 1,809 were satellites and 5,310 were debris. Since the launch of Sputnik 1 in October 1957 19,759 objects have been orbited. Vanguard 1, launched by the US in March 1958 is the oldest satellite in orbit. The Soviet Union's oldest spacecraft is Luna 1 - launched in January 1959, the probe is in orbit around the Sun. The Apollo 11 Lunar Module is the oldest manned spacecraft in space - the historic craft that took the first men to the Moon is in Lunar orbit. The oldest Soviet manned spacecraft to remain in orbit is the Salyut 7 space station, launched in April 1982. During 1988 67 satellites reentered the Earth's atmosphere. They included Intelsat 3 F-5 - launched in 1969 by a Delta rocket. It was placed in an incorrect orbit, and finally burnt up in the atmosphere on October 14, 1988.

Cosmonaut Conscript

Soviet bureaucrats have been attempting to prosecute Mr Sergei Krikalev, aged 30, with draft-dodging. He failed to report for reserve duty in the Soviet army several months ago and has now been threatened with legal action. Mr Krikalev, although willing, has been unable to take his posting due to the fact he is currently 349 km above the Earth onboard the Mir space station. The Soviet press agency Tass reported the story under the headline "Space is no escape from dim-wit bureaucrats, cosmonaut learns".

Freedom Cupola

McDonnell Douglas has delivered a metal, wood and glass mock-up of a Freedom Space Station Cupola to NASA's Johnson Space Center. Freedom will have two similar cupolas attached to the forward resource nodes with one facing Earth and the other spaceward. These symmetrical octagon-shaped rooms are encircled with windows to provide clear views for astronauts involved in operations such as the docking of a Space Shuttle and the operating of tele-robotic devices. The cupolas will be used by NASA and McDonnell Douglas personnel to be sure the size, shape, interior design and work stations are suitable for those tasks.

Hubble Telescope Move

A modified US Air Force C-5A Galaxy will be used to transport the Hubble Space Telescope from Lockheed's Sunnyvale facility to the Kennedy Space Center in August. The telescope is to be launched by Discovery in December. It is currently undergoing final assembly and checkout activities in a clean room at the Sunnyvale facility.

Nomination for NASA Chief

Ex-astronaut Richard Truly has been nominated for the post NASA Administrator, succeeding James Fletcher who officially retired on April 8. Truly's nomination will have to be approved by Congress.

Truly will take his post at a difficult time for NASA. The agency's $13.3 billion budget has yet to be approved and once again space station Freedom is threatened by cuts in funding. Another major problem for NASA is also the 'brain drain' - top management and engineering officials are leaving the agency in large numbers for better paid jobs in the private sector.

Truly has had a long association with space flight: he became an astronaut in December 1965 when he joined the USAF Manned Orbiting Laboratory (MOL) programme. He was transferred to NASA in 1969 following the cancellation of the MOL project. Truly became a member of the support crews for Skylab 2,3 and 4 and the Apollo Soyuz Test Project. In 1977 he was a member of the Enterprise crew for the shuttle drop tests from a 747 aircraft.

In November 1981, 22 years after joining NASA, Truly made his first space flight aboard the second shuttle mission, STS-2. He went on to command STS-7 - Challenger's second flight and the first launch and landing at night.

Shortly after his second shuttle mission,

Truly on Challenger's flight deck during STS-7

Truly left the space agency to become Commander of the US Navy Space Command.

He returned to NASA in February 1986 as Associate Administrator for Space Flight and found his first task was to head the NASA investigation into the Challenger accident. Truly steered the shuttle programme back on track, his efforts culminating in the successful flight of Discovery in September 1988.

First Commercial Rocket Launch Successful

The first private commercial spacecraft was launched on March 29, by Houston-based Space Services Inc. (SSI), carrying a NASA-sponsored payload of microgravity experiments.

SSI's two-stage, solid-fuelled Starfire 1 rocket lifted off from the White Sands Missile Range in New Mexico at 9:41 a.m. CST, transporting the payload owned by the Consortium for Materials Development in Space at the University of Alabama-Huntsville 187 miles high and 50 miles down-range for a suborbital flight of 14 minutes 11 seconds.

Former astronaut and Flight Crew Operations chief Donald K. "Deke" Slayton, now president of SSI, said the launch of the 625.45-inch rocket could not have been any better.

Jim Davidson, an analyst for SSI, said the launch was noteworthy not only because it was the first commercial launch in the US, but also because it was launched on time and a day ahead of schedule.

The 630-pound payload contained six experiments designed to investigate the effects of microgravity on electroplating, dispersion of molecules, polymer foam production and polymer separation. The experiments experienced 7 minutes 6 seconds of near-weightlessness. The materials development consortium is one of 16 commercial space development centres sponsored and funded by NASA.

The payload's parachute deployed perfectly and the full payload was recovered, Davidson said. It was returned to Huntsville for evaluation by the principal investigators.

"There was a considerable amount of surprise and pleasure on the part of one principle investigator at the results of the foam experiment," Davidson said. When the payload canister was opened, an apparently perfect sphere of the foam was discovered, exactly as had been expected, he explained.

While there have been previous small private launches, this was the first payload large enough to require licensing by the Department of Transportation (DOT). Eight more commercial launches are scheduled this year, according to the DOT.

The launch represented a major boost to the commercial launch industry, which hopes to be able to support as many as 100 suborbital and 40 orbital launches every year.

SSI launched a dummy payload in 1982 from Matagorda Island after obtaining clearances from numerous government agencies because no private space launch had been attempted up to that point. This launch was the first under the National Space Policy created by President Reagan in February 1988 in an effort to encourage the commercial utilisation and exploitation of space following the Challenger accident.

Japan Signs Space Station Agreement

NASA Administrator Dr. James C. Fletcher and Japanese Ambassador H.E. Nobuo Matsunaga signed a Memorandum of Understanding (MOU) on March 14, for cooperation in the detailed design, development, operation and utilisation of the permanently inhabited space station Freedom. The agreement was signed at a brief ceremony at NASA Headquarters.

Comparable MOUs with the European Space Agency and Canada were signed, along with an intergovernmental agreement, in a ceremony held at the U.S. State Department last September. The MOUs signed between NASA and its three partners focus on programmatic and technical aspects of the cooperative effort and establish the management mechanisms necessary to carry out the Freedom programme.

The MOU with Japan will become effective upon written notification by each party that all procedures necessary for its entry into force have been completed. Until then, Japan will continue to work under an extension of the MOU signed with NASA in May 1985 at the start of the space station programme's definition and preliminary design phase.

Under the agreements, Japan will provide the Japanese Experiment Module (JEM). The JEM, to be permanently attached to the space station base, consists of a pressurised laboratory module, at least two experiment logistics modules and an exposed facility, which will allow experiments to be exposed to the space environment.

Experimenters will conduct materials processing and life sciences research in the laboratory module, while the logistics module can be used to ferry materials between the station and Earth and for storing experimental specimens and various gases and consumables.

Space station Freedom is an international space complex to be placed into orbit in the mid 1990s.

External Tanks to be used for Research

NASA and the University Corporation for Atmospheric Research (UCAR) of Boulder Colorado have signed an agreement that establishes UCAR's use of Space Shuttle External Tanks for suborbital experiments.

UCAR is interested in conducting experiments to be contained in the 5,000 cubic foot intertank area, between the fuel and oxidiser tanks. The experiments would be conducted during the suborbital trajectory of the External Tank following its jettison from the shuttle and prior to its destruction during reentry.

Under the terms of the agreement, NASA will assist UCAR in developing the suborbital use of the intertank areas for its experiments. The agency has agreed to make the space available on up to five External Tanks. The use of the intertank will not require any operational or programmatic changes in shuttle operations.

Roelof Schuiling

A reception was held at the Science Museum in London on February 22. to commemorate the commissioning of the Skynet 4B satellite (Left to right) Mr John Holt, Managing Director of British Aerospace Space Systems, Mr Tim Sainsbury, Parliamentary Under Secretary for Defence Procurement and Sir Peter Anson, Chairman of Marconi Space Systems. See Society News for further details and p.168 for a special feature on the Skynet satellite. *Marconi*

CORRESPONDENCE

Energia Motors

Sir, In 'Correspondence', ***Spaceflight,*** November 1988, p.438, Mr. A.T. Lawton suggests the Soviet Energia core stage engines are of the plug nozzle design. The photograph (right) shows the main engines of an Energia test vehicle, taken from a Soviet TV film [1]. It clearly shows the engines are of the bell nozzle design.

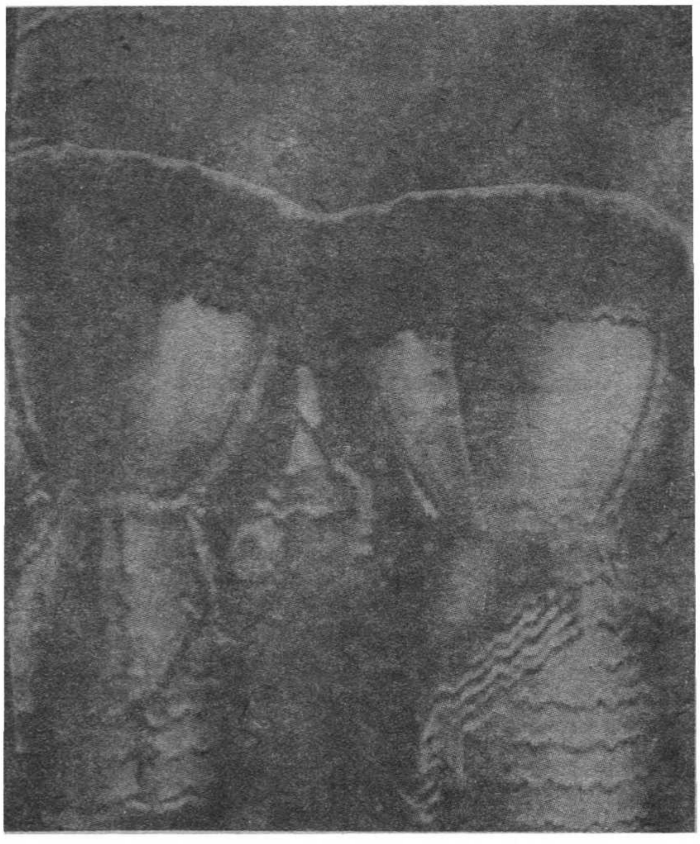
In the February 1989 issue of ***Spaceflight*** Mr. Tony Devereux suggests that the core stage of Energia is 60 m high by 8.5 m diameter. The actual dimensions of the Energia are core stage 59 m high, 8 m diameter, boosters 38 m high, diameter 4 m [2].

In answer to the correspondence over the Energia model displayed by Glavkosmos at Brighton during SPACE '87, the model is probably not very accurate but it gives a good impression of how large Energia is. I like to compare it with the aircraft models displayed in travel agents, not very accurate but they look impressive.

P. MILLS
Kings Lynn, Norfolk, UK

Acknowledgements and References

1. Special thanks to Mr. Neville Kidger, Mr. Phillip Clark and Mr. Rex Hall.
2. *Energia and Buran, The Soviet Space Union,* Tim Furniss, Flight International, February 1989, p.22-26.



(Right) Close up of the Energia main core-stage engines. *P.Mills*

'Correspondence' continues on p.170.

Top Pilots Ready to Fly Buran

The Buran test pilots: (Anti-clockwise, starting top left) Volk, Zabolotski, Tresvyatski, Sheffer, Toboev, Stankiavicius and Sultanov. *All Photos Novosti*

If Soviet officials decide their shuttle is ready to fly manned, two of the test pilots pictured above will be seated in Buran's flight deck when she blasts off for the second time - probably before the end of the year. Soviet journalist, ***Victor Golovachev,*** **talks to the leader of the pilots who will take the Buran space shuttle into orbit.**

Under the leadership of 51-year-old Igor Volk, who spent twelve days in space in 1984, seven of the Soviet Union's top test pilots are training intensively for Buran's future flights into space.

When the group was formed in 1978 it numbered ten; but in that first year, pilot Kononenko was killed in a take-off accident.

More recently pilot Shchukin lost his life in a SU-26 test flight and last summer, pilot-cosmonaut Levchenko died of a brain tumour just eight months after returning from the Soyuz TM-4 mission to the Mir space station.

While future fight details and space crews are being decided on, the remaining seven - Stankiavicius, Tolboev, Sultanov, Zabolotski, Tresvyatski, Sheffer and Volk himself - are test flying. It keeps them fit, says Volk.

Test flying gives the pilot unique experience, the ability to foresee developments and, if necessary, act contrary to trained reflexes. In a flying emergency, a pilot naturally seeks a way out. A test pilot, however, carries the situation to the limit. His expertise enables him to plunge into a spin and yet find a way out. Test piloting experience is essential for the Buran trials.

Of course, the group does theoretical

and simulator training, but they are not as instructive as an actual test flight.

On one occasion in the shuttle trials the new plane piloted by Volk braked sharply along the runway prior to take-off. It was only after take-off that it was noticed that all the rubber had been burnt off the wheels. Ordered to eject, Volk did not obey and landed safely against all the odds.

I asked Volk about when the first shuttle plans were conceived: "It began in the first half of the 1960s. Suspended from a large aircraft one prototype rose to a height of 8-10 km, separated and landed after a short flight.

"There were several problems to solve: heat insulation in particular. The nose had to withstand temperatures of up to 1,500°C. Many experiments were carried out on the ground before we proceeded to the test flight stage.

"The first craft to test our new heat insulation tiles was launched in 1982. We then put up some satellites in '83 and '84. They all yielded priceless information on heat-insulation." Volk is referring to the Cosmos 1374, 1445, 1517 and 1614 mini-shuttles.

"Before Buran went into space, its sister ship had performed several flights within the atmosphere.

"Like the US Space Shuttle, the Buran engines do not work in the Earth's atmosphere: they return from orbit and land as gliders. But for atmosphere trials Buran's unnamed sister craft was fitted with four turbojet engines, enabling her to take off and land as aircraft do.

"On November 10, 1985, Stankiavicius and I were to take Buran on her maiden flight. We took off, rose to 1,000 metres, circled the airfield and landed twelve minutes later to a hero's welcome.

"The second, 36-minute flight took place on January 3, 1986. The 24th and final test flight took place on April 15, last year, seven-and-a-half months before Buran went into space.

"During the trials, Levchenko, Shchukin, Bachurin and Borodai flew her with the aim of testing the possibilities for a radio-controlled unmanned landing."

As well as the comprehensive flight testing, there were over 1,400 bench trials and in the flight simulators the crews 'flew' a total of 3,200 hours at the controls.

"In the flying-lab tests we developed the most sophisticated automatic landing systems; studied runway approach manoeuvring and acted out co-ordination between the ground and shuttle systems," Volk explained.

"For these tests we used the TU-154 and Mig-25 aircraft because, although Buran and the TU-154 have vastly different flight patterns, Buran's descent path is very steep and she levels out only before landing. We only had to 'spoil' the TU-154's aerodynamics slightly to simulate our shuttle's flight.

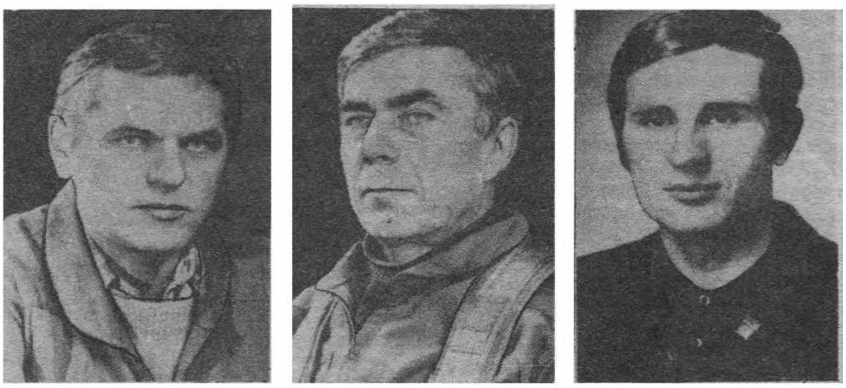
"Our flying labs performed over 1,000 simulated automatic unmanned landings. The testing was conducted at the Flight Research Institute and the Baikonur Cosmodrome, where Buran eventually made its historic successful unmanned landing."

"Any test pilot will tell you that 1,000 test flights is a lot. Each one was thoroughly prepared beforehand and the results meticulously analyzed afterwards. The pilots spared no effort. Their skill, experience and ability to assess the changing in-flight situation were all crucial to the success of the project."

Volk also praises the professionalism of the manufacturers who also played a major role in Buran's success. And he sounds a cautious note concerning Buran's future, particularly concerning the question of whether its next flight is manned or not?

"The first success should not produce such a euphoria that the strict technical standards required are lowered in any way. Space forgives no mistakes and a lot still has to be done before a manned flight aboard Buran can be seriously considered."

Spaceflight gratefully acknowledges the assistance of *Soviet Weekly* in the production of this report.



Three of the Buran test pilots have died since their selection: (Left to right) Shchukin, Levchenko and Kononenko.

Mir to Be Left Unmanned

Soyuz TM-8 Indefinitely Postponed

Cosmonauts Volkov, Krikalev and Polyakov are to return to Earth on April 27, leaving the Mir space station unmanned for the first time since February 5, 1987. The flight of a replacement crew, scheduled for April 19 has been indefinitely postponed.

News first reached the West when an ABC television team visited Moscow to make arrangements for a live television link-up between Mir and the Shuttle Atlantis. The Soviets were strangely uncooperative and finally revealed to the ABC team that the link-up would not be possible because Mir would be unmanned at the time of the Shuttle flight.

The Soviet news agency Tass confirmed the story on April 11 when it reported: "The cosmonauts are to return to Earth on April 27, while Mir will continue its flight in the unmanned mode." By this time the crew had already began preparations to leave the station. Their work included taking stock of the onboard equipment and consumables and carrying out maintenance work.

On April 10, Mir's orbit was boosted by 50 km into a 400 x 372 km 'storage orbit.'

It seems the space station is being left unmanned as an economy measure. The launch of a Soyuz craft costs about $20 million. In addition, there is the cost of launching regular Progress supply vessels and the operation of ground and tracking facilities. To continue this expenditure - when the Mir programme has no clear goals until the launch of the first 20 tonne module later this year - would provide ammunition to opponents of the space programme. There has been growing criticism of the size of the space budget in the Soviet press and it has also been an issue in the recent Soviet elections. The space programme is becoming an area for intense debate. Soviet space officials appear to be making voluntary cuts to their budgets in an attempt to appease the increasing number of critics.

The Soviets are expected to return to space when the Mir modules are ready for launch. A new crew will probably be launched in the Autumn. However the Soviets may wait until early 1990 before manning the station again.

Above the Planet

Salyut EVA Operations

Regular *Spaceflight* correspondent *Neville Kidger* concludes his review of spacewalks made from the Soviet Union's Salyut series of space stations. 1984 was a banner year for space walks from Salyut 7. Last month's instalment saw the docking of Soyuz T-12 on July 18, 1984 bringing the cosmonaut complement aboard Salyut for a time up to six. We now pick up the story recalling that on September 9, 1983 Salyut 7 suffered an oxidiser leak and it had been decided that the next crew would effect a full restoration of the Combined Engine Installation (Soviet acronym ODU).

By Neville Kidger

Completing a Job: August 8, 1984

During Soyuz T-12's visit, Dzhanibekov had given demonstrations and training to Kizim and Solovyov on the work required to seal off the oxidizer pipe. The training included suited-up rehearsals with an actual pipe section mounted on Salyut's wall. Videotapes were also provided showing Dzhanibekov in the Star Town hydro tank.

During the previous four EVAs devoted to the ODU fixing the cosmonauts had succeeded in installing two bypass lines on the reserve fuel supply system but the pipe now had to be sealed off. For this purpose a Portable Pneumo-Press (PPT) was developed. It consisted of a cigar-shaped gas container filled with compressed air, a piston-type actuator and a clamping device containing fixed and movable clamps. It was delivered to the station, along with other tools on Progress and Soyuz T ships in June/July.

At 0720 GMT on August 8, Kizim and Solvyov again began to don their space suits. This would be the tenth time these suits had been used by EVA cosmonauts.

Atkov remained in the work compartment. At 0846 GMT the hatch was opened for the seventh time of the 1984 tenancy and the two cosmonauts began to move along Salyut's exterior.

For the first time the men did not have a Progress or Soyuz T attached to the rear docking port which meant that the men had to deploy the work platform that they had used earlier into the outer diameter of the Salyut's work compartment.

Having secured the platform and their tool boxes, the men opened up the thermal skin of the engine section again. This was accomplished by 1030 GMT. Solovyov then located the required pipeline "in the cobweb of hydromanifolds".

Solovyov reported sometime later that the PPT had been secured to the line and that its valves were opened. 250 atmospheres pressure applied 5 tonnes of closure to the line to seal it. Kizim later reported to the FCC that "All is normal here". The cosmonauts had ignored medics advice to rest during the operation.

After replacing the thermal covering for the final time, the men packed away their tools and began to make their way back to the front of the station. Before returning into Salyut the men used a special holding and cutting tool to remove four photo-electric elements of one of the solar panels for analysis back on Earth. The sample was used to study the process of aging and degradation of silicon solar cells. The tool was devised so that the men could cut the solar panel segment without coming into contact with it with their gloves. Atkov later said the men's hands were scarred "as if they had been in a fist fight".

At 1346 GMT the hatch was closed for the final time of the 1984 occupation after an EVA of five hours - a Soviet record. It brought their total time outside the station to 22 hours 45 minutes. The only man with more time outside his spacecraft now was the American Eugene Cernan (24 hours 11 minutes).

The only EVA task left for the men was testing of the beam builder. If this task was accomplished before the launch of the Shuttle 61-B mission the Soviets could lay claim to yet another first.

Solvyov was later to describe his "great regret" at having to finish the men's sixth EVA.

1985: A False Start

Having restored the Salyut's ODU to working status again the Soviets planned a full scheduled of activities for 1985. A three man crew - Vladimir Vasyutin, Viktor Savinykh and Aleksandr Volkov - were to man the station. A Kosmos heavy module would be docked with the forward docking unit, possibly after a visiting crew had departed. EVAs were planned, at least two which would see the third set of solar panels supplemented with DSB's (Vasyutin/Savinykh) and another one, or possibly two, to test a beam erection device called Ferma Postroitel.

However before the three men could be launched power was lost on Salyut 7 and contact with the ground was severed. A two-man team of Vladimir Dzhanibekov and Viktor Savinykh was formed to fly to Salyut, dock manually with the dormant station and reactivate it.

The two men accomplished this difficult feat in June 1985 paving the way for the continued occupation of the station and the realisation of the original planned flight.

Before the original crew could be re-formed on the station the Soviets took the opportunity to conduct the EVA to attach the third set of DSBs.

A Busy Day: August 2, 1985

Whilst Savinykh had trained for an EVA to add DSBs during his long-term flight, Dzhanibekov had made an EVA during the Salyut T-7 visit for a special purpose only - to test a new piece of equipment.

However, Dzhanibekov had trained for a long-term flight on Salyut 7 before being put in charge of the Soyuz T-6 Soviet/French crew due to the "illness" of the original commander, Malyshev. His training probably included DSB additions in readiness for the long flight.

Salyut's hatch was opened at 0715 GMT on August 2. The two men carried the DSB containers to the solar panel. Using the winching and other tools they unfurled the first of two panels and, after completing that operation, waited as the FCC commanded the large panel to rotate 180 degrees so that its other side faced the men. The second panel was then unfurled. TV was shown during the EVA of the two men floating around the base of the panel.

On one of the main panels they fastened an experimental sample of a solar cell which would later be removed for a study of the effects of outer space's vacuum and radiation factors upon it.

Moving back to the hatch the men installed a French-made detector block called COMET. It consisted of four pairs of rectangular-shaped boxes mounted on a central spine. The boxes were placed on Salyut's exterior in the closed position and later opened to capture dust from comets Gicobini-Zinner and Halley.

Dzhanibekov and Savinykh then collected up cassettes with samples of bio-polymers and various structural materials for return to Earth and replaced them with new ones. The Soviets said that the men fulfilled expectations for the EVA.

In addition, the two also checked out new EVA suits which featured illuminated control panels and improved shoulder belts. Part of the rubber shell was made sturdier. The men's electrocardiograms were recorded on magnetic tape by portable medical equipment and other physiological parameters were also measured.

Dzhanibekov and Savinykh's EVA lasted for about five hours.

A Flight Cut Short

Savinykh remained on Salyut with Vasyutin and Volkov in September 1985. Georgi Grechko returned to Earth with Dzhanibekov after the first partial crew rotation in space history had seen the original crew begin work on Salyut 7.

With the solar panels supplemented, the only EVA task left for the men, apart from emergencies, was testing of the beam builder. If this task was accomplished before the launch of the Shuttle 61-B mission the Soviets could lay claim to yet another first. (On the Shuttle flight astronaut Sherwood Spring and Jerry Ross would test assembly techniques for large structures in orbit; previous large space structures have included Skylab's solar parasol and sail, the KRT-10 antenna and Shuttle 41-D's 102ft deployable solar array).

The first part of the programme was successful. The Kosmos 1686 heavy module docked with Salyut's front port on October 2. However, by mid-November the mission was in deep trouble with Vasyutin suffering from an as-yet-undisclosed illness.

The malaise forced a quick termination of the mission and on November 21 the men were back on Earth. Their mission had been due to continue until mid-March 1986.

Last Post for Salyut 7

On February 20, 1986 the Soviets placed the currently-operational Mir base block into orbit. Although the original plans for its occupation are not known, what is certain is that the early end to

the Soyuz T-14 mission meant that a crew had to be found who could fulfil a mission to both Mir, to check it out, and Salyut, to complete the work there.

Vladimir Solovyov was working at FCC when he was called to train for the flight. He would fly with Kizim on the epic mission.

Launched on March 13, the two men spent 51 days onboard Mir before flying over to Salyut/Kosmos 1686 at the beginning of May in the first operation of its type. For the two men it must have been a pleasure to renew acquaintances with the station.

Girder Constructors: May 28 and May 31, 1986

At 0543 on May 28, Kizim and Solovyov began their seventh EVA from Salyut 7. Within 15 minutes they collected and stored inside the transfer compartment cassettes containing bio-polymers and materials samples and the French COMET dust collector.

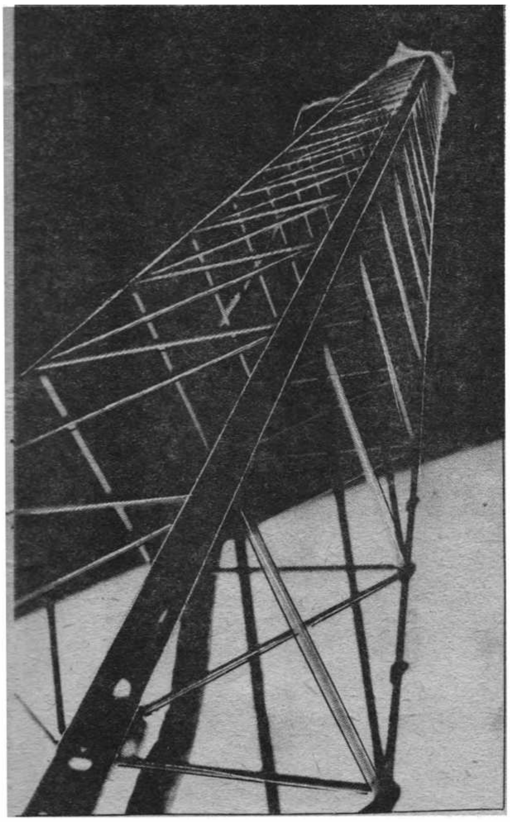
Their next task involved setting up a platform on the transfer compartment upon which they attached a one metre diameter, one metre tall cylinder with a weight of 150 kg. During this activity the men were heard breathing heavily. A TV camera was then set up on the platform.

During the next orbit the men, working in the same suits as Dzhanibekov and Savinykh had used, conducted the first part of the Mayak (Beacon) experiment.

The cylinder, named, URS, contained a hinged metal lattice-work girder weighing 20 kg which was a rhombus 40 cm x 40 cm in cross section. The device was developed by V. Lapchinski of the Paton Institute (he also developed the Isparatel spraying device and the URI tool used earlier).

The girder could be deployed in three modes - manually, semi-automatically and automatically. The task for the cosmonauts on this planned 3-hour-long EVA was to test how the girder performed in open space.

In May 1986, cosmonauts Kizim and Solovyov deployed this large girder outside the Salyut 7 space station. They had been launched to Mir in March and transferred to Salyut 7 in early May. *Novosti*



At 0729 GMT the cosmonauts returned TV pictures of the girder stretching 15 metres above the station against the backdrop of Earth. The pictures were historic - they were the first shown live by the Soviets of an EVA in progress. The cosmonauts had used automatic control to unfurl the girder. They were to test all the deployment options during the EVA.

Towards the end of the EVA the men installed an optical device, called BOSS, on one of Salyut's windows. This was part of an experiment to test an optical wavelength transmitter for telemetry. Signals received from an instrument on the girder were to be converted into digital form by the optical device which then transmitted them via a 3 milliwatt laser through the porthole to the BOSS receiver were they are converted back into electrical signals for transmission to Earth. The unit featured triple redundancy in its main elements to improve reliability.

Kizim and Solovyov closed the hatch after stowing the girder back in the cylinder. They had been outside for three hours and 50 minutes.

The Soviets spoke of future versions of the girder being several kilometres in length and being used to link space settlements together in orbit.

On May 30 the Soviets announced that the men would conduct another EVA the next day - the first time the Soviets disclosed timings (although in 1984 they said further EVAs would follow in their report of the ODU restoration work).

Kizim and Solovyov began their eighth excursion outside Salyut 7 at 0457 GMT on May 31. TV was returned of the cosmonauts mounting a flat package of instruments on the top of the retracted girder. The package contained two instruments on the top of the retracted girder. The first was Fon (Background), which had a detector for measuring the density of the 'atmosphere' around the station. Solovyov noted that gases were separated out of the station's elements, such as the shield vacuum insulation. Such outgassing could interfere with precision optical instruments. As the cosmonauts extended the girder, with some difficulty, to a height of 12 metres, the Fon instrument measured the density of the surrounding gases and relayed them via the BOSS system to the ground.

The second instrument system mounted on the package was a seismic unit to monitor vibrations of the girder as it was extended. A light beacon was fitted atop the girder to give the men a reference point: via a TV camera, any oscillations of the structure could be monitored.

Live TV was shown of Kizim at the base of the girder. The cosmonaut then began to move along the length to cause vibrations and the girder was seen to rock slightly. Kizim stopped just a short distance up the girder. It was noted that the girder could be used to carry a cosmonaut, if required, but the first steps with the device were made near the station.

The girder was then folded back into its canister. The instruments were left attached. The men then used the URI tool, first tested by Dzhanibekov and Savitskaya to weld elements of the frame's structure. The URI had been modified so that it had a new crucible and was easier to operate. The Soviets said that by welding such lattice-and-pin frames "space assembly and construction workers" are to assemble large space structures.

With the URI tests accomplished the men had two more tasks to perform. They mounted a micro-unit test for deformations on the exterior of the station. The unit was to strain samples made from an aluminium and magnesium alloy. The results would give experts the test data they need to forecast the performance of materials from which large-scale space structures would be made, the Soviets said. Results of the test were to be telemetered to Earth over a lengthy period.

The men also removed the small piece of solar cell material that had been left outside by Dzhanibekov and Savinykh in 1985.

The cosmonauts went back into Salyut after an EVA lasting five hours. Together the two men had set world records for the number of EVAs - eight - and the time spent on them - 31 hours 36 minutes. These records are expected to stand for a long time.

Kizim and Solovyov returned to Earth on July 16 after another short stay on Mir. Salyut 7/Kosmos 1686 were boosted to a higher orbit in mid-August 1986. By Autumn 1989 the complex will again be close to Mir. The Soviets have said they intend to visit the station again and perhaps retrieve the samples. Whether this visit will be a fly around inspection or a docking and stay inside is unclear at the time of writing. The Soviets have announced the Buran orbiter is to retrieve 'blocks' of the complex.

Conclusion

The Soviet experiences outside the Salyut space stations undoubtedly strengthened their confidence in the ability of cosmonauts to do a wide variety of tasks in open space. The long delay in conducting such operations - by the time they made the first Salyut EVA the Americans had amassed over 200 hours of EVA experience - was due to their early problems with the civilian Salyut programme.

Finally, there was a coincidence with Salyut's first EVA and the first EVA on Mir. As with Salyut 6 that EVA, on April 11, was to aid the docking of two spacecraft (Mir/Kvant) and, perhaps more remarkable still, one of the participants was Yuri Romanenko who was involved in the first Salyut EVA. The EVA was unplanned and dangerous but the experience of Salyut ensured the Soviet's confidence and willingness to undertake the venture during the early days of the Soviet's permanent manning of the Mir complex.

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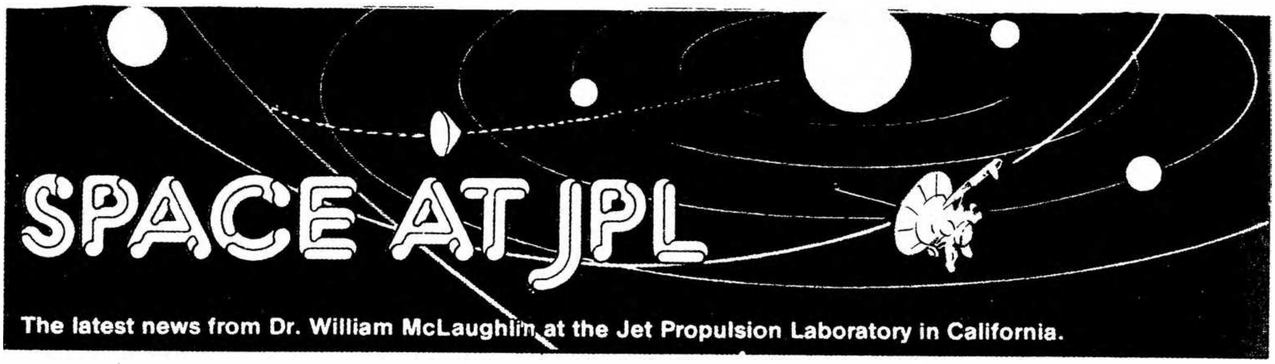
Finally, the writer thanks the following individuals for providing, over a number of years, data and translations which were used in this article: Phillip Clark, Ralph Gibbons, Ralph Gibson, Rex Hall, Mark Hillyer, James Oberg.



Mission to the Sun

The Sun is of exceptional practical interest to us, its dependents, and also furnishes a splendid avenue into the realm of stellar astrophysics. However, it is not easy to design a mission to our star. First, the Earth travels around the Sun in a nearly circular orbit at approximately 30 km/s, and this velocity vector must be forcibly altered in order to "drop into" the Sun. Second, at close range the Sun produces a very inhospitable environment for a spacecraft. "Solar Probe" is a mission under study at JPL which, if approved, could bring a spacecraft as close as three solar radii above the solar surface toward the end of the next decade (one solar radius equals about 700,000 km).

Solar Probe has been under consideration for several years (see the March 1983 edition of this column and the August 1984 issue of *JBIS*: in both publications the mission is referred to by its previous designation, "Starprobe"), and during this time the study has been managed by James E. Randolph of JPL. The primary objective of the mission is the study of the solar wind and its related fields, waves, and particles environments in the region of 4 to 60 solar radii from the centre of the Sun, where no spacecraft has previously ventured.

The basic mechanism of energy generation within the Sun comes from thermonuclear fusion, wherein hydrogen is converted into helium - see last month's column for an historical review of our growth in understanding the source of the Sun's energy - and the temperature at the centre is about 15 million degrees Kelvin (°K). Material in the solar interior is in "the fourth state" of matter, plasma, which consists of the nuclei of atoms together with their stripped orbital electrons (the other three states are solid, liquid and gas). The plasma on the whole is electrically neutral. The solar interior is so densely packed that a photon created at the centre of the Sun takes, on average, 30,000 years to migrate to the solar surface! (The original packet of energy, perhaps a high-energy x-ray photon, is transformed many times on its "walk" by interactions with the plasma and emerges at the surface as a photon of visible light.) If the photon were able to travel on a straight line, its journey from the centre of the Sun would take just over two seconds.

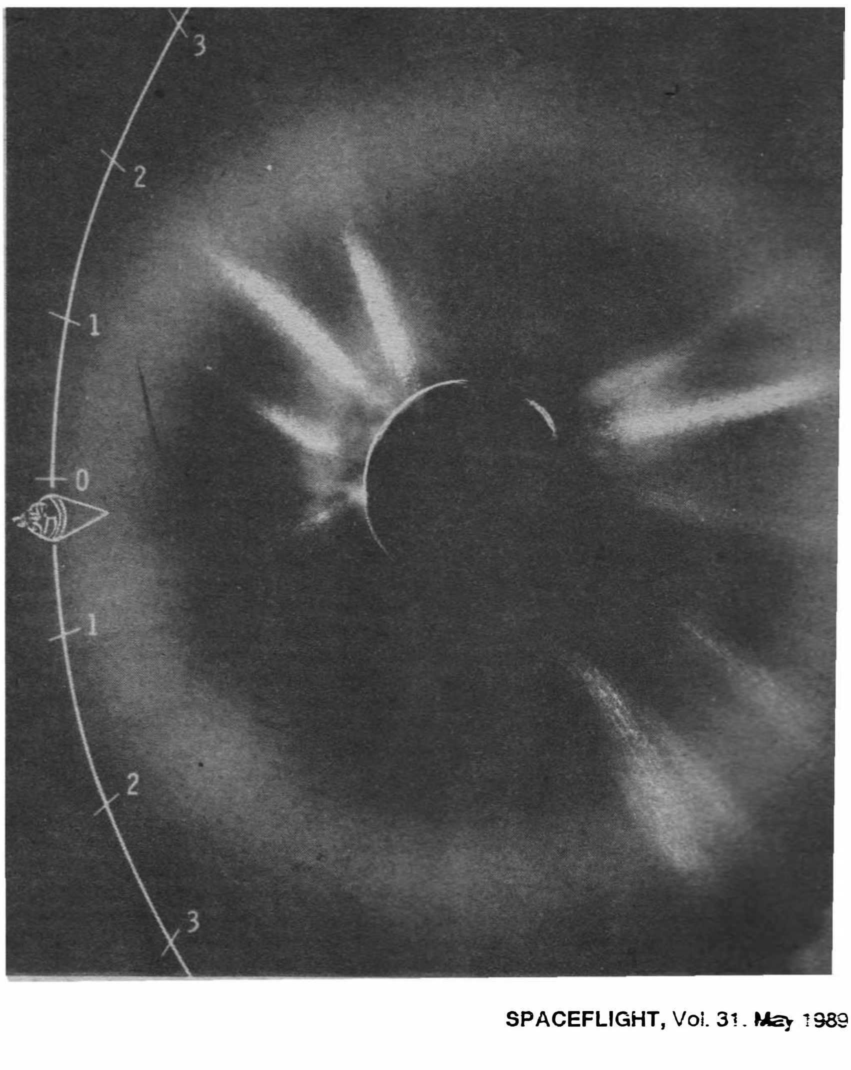
The surface of the Sun is called the photosphere and has an effective temperature of 5800°K. Above the photosphere lie the chromosphere and the corona; the latter is very hot, with a kinetic temperature of a few million °K, and does indeed constitute a startlingly beautiful crown for the Sun during a total eclipse.

The mechanisms by which the corona becomes so hot are an active area of research. A consequence of the hot corona is that the Sun cannot contain all of the plasma in the outer corona and a "solar wind" blows outward into the solar system, a phenomenon first explained theoretically by Eugene N. Parker (1958).

The solar wind is mostly composed of protons and electrons, reflecting the predominance of hydrogen in the Sun, and exerts a profound influence on the structure of the solar system. Not long after condensation of the Sun from the solar nebula (almost 5,000 million years ago), fierce solar winds cleared out much dust and gas from the early solar system. Today, a more benign solar wind impacts the Earth's magnetic field at about 400 km/s and helps mould the teardrop-shaped magnetosphere which enwraps our planet (Jupiter, Saturn, and Uranus have significant magnetospheres, as measured by spacecraft, and so probably does Neptune). Somewhere between 50 and 100 A.U. (an "A U." or "Astronomical Unit" is the distance from Earth to Sun and is equal to about 150 million km) the influence of the solar wind ceases - at the heliopause - and with regard to this measure interstellar space begins. It is possible that the Voyager or Pioneer spacecraft may survive long enough to traverse the heliopause and measure its properties. Exciting images constructed from observations by the Infrared Astronomical Satellite (IRAS) in 1983 show such transition zones for two stars; see p.241 of the March 1989 issue of *Sky and Telescope*.

Solar Probe should be able to detect where the solar wind accelerates from subsonic plasma flow to supersonic flow. It is expected that this takes place somewhere between 1 and 10 solar radii from the centre of the Sun, with the

The proposed Solar Probe Mission may fly within three solar radii of the surface of the Sun, sometime around the turn of the Century. (The image of the Sun was obtained during NASA's Skylab mission) *NASA*



upper bound more likely.

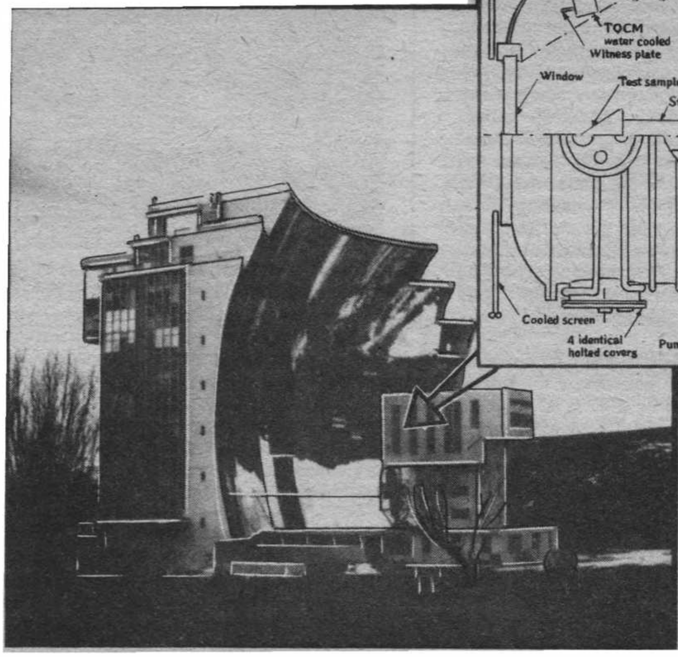
Shielding from the fierce glare of the Sun is a prime necessity for Solar Probe and will be accomplished by means of a frontal cone of tough carbon-carbon: sufficient to withstand the heat of nearly 3000 Suns (by convention, 1 Sun is the solar radiation intensity felt at Earth). At its closest approach to the Sun, the Helios spacecraft experienced the intensity of nine Suns. The principal design challenge for the solar shield is not directly related to thermal protection but rather to minimising the rate of mass loss through sublimation. This rate will peak at about 2.5 mg/s from the glowing shield in the vacuum of space.

It is difficult to create conditions on Earth for an extended period of time that allow one to test large pieces of material in a simulated near-solar environment. The French solar furnace at Odeillo Font-Romeu in the Pyrenees is capable of generating an intensity of up to 15,000 Suns and has been employed in testing carbon-carbon in a space vacuum for Solar Probe. The energy for the furnace is, appropriately, derived from the Sun; the valley in which the furnace is located is populated by primary mirrors which track the Sun and reflect it onto a parabolic secondary mirror for focusing into the test chamber that, in Randolph's words, "only Mephistopheles would enjoy."

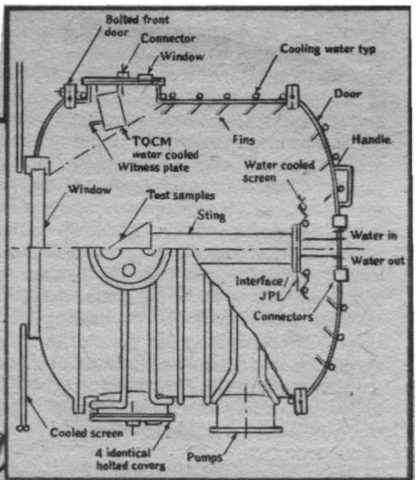
Jupiter serves as a gravitational broker for many interplanetary missions, and Solar Probe plans to use its services once more: to exchange the angular momentum of the spacecraft, outbound in a "fat" ellipse, for a reversal of course into a near straight-line approach to the Sun (actually travelling along a "thin" ellipse with eccentricity 0.992; a circle is a maximally obese ellipse, with eccentricity 0). The joint ESA/NASA Ulysses mission, scheduled for an October 1990 launch, also uses a Jovian gravity assist, but to flip the spacecraft significantly above the ecliptic for its journey of exploration above the poles of the Sun.

The gravity assist from Jupiter will be arranged so that Solar Probe's trajectory at the Sun is a pole-to-pole transit, accomplished in a mere 14 hours. At closest approach to the Sun, perihelion, the spacecraft will be travelling at 300 km/s. After encounter, the spacecraft will drift out to Jovian range again and, if its subsystems have survived the first solar encounter, be available for a second close passage, possibly even closer than the first one, about five years later.

CNRS/CNES Test Facility in Odeillo, Romeu, France



CNES Vacuum Chamber



The French solar furnace at Odeillo Font-Romeu in the Pyrenees is capable of achieving an intensity of thousands of Suns in a test chamber and has been used to test the carbon-carbon shield for NASA's proposed Solar Probe mission. Shown is the large secondary mirror which focuses sunlight from a set of primary mirrors (not shown) that track the Sun. *CNRS*

The estimated mass of the spacecraft is 1000 kg, with 200 kg of this amount devoted to the shield which must be solar pointed throughout the perihelion passage. Three-axis stabilisation has been selected as the means of attitude control for the spacecraft, but a small package of instruments will be spun at the apex of the shaded zone (umbra) behind the shield. Fields-and-particles experiments enjoy the wide fields-of-view afforded them by the spinning state. Power will be supplied by radioisotope thermoelectric generators rather than solar panels, a seemingly strange state of affairs for a solar mission, but the distance of Jupiter from the Sun precludes the choice of panels.

Some consideration is being given to the possibility of using the "Waverider" concept of a high-velocity redirection of the spacecraft's trajectory at Earth and/or Venus, in place of the gravity assist at Jupiter, by means of an aero-gravity manoeuvre. Under investigation by the Association in Scotland to Research into Astronautics (ASTRA), the Waverider was invented in the late 1950s by Professor T.R.F. Nonweiler, a founder member of ASTRA. A Waverider vehicle rides on its own hypersonic shockwaves and has potential for application to hypersonic airliners as well as bending the velocity vectors of spacecraft by passage through planetary atmospheres. The aero-gravity assist was suggested for this mission in 1977 by Randolph, and the Waverider would seem to fulfil the concept.

Solar Probe is an attractive mission because it scores high in each category of the triad of science, applications, and technology. It also quickens the pulse to think of venturing so close to the central fire.

The Space Frontier

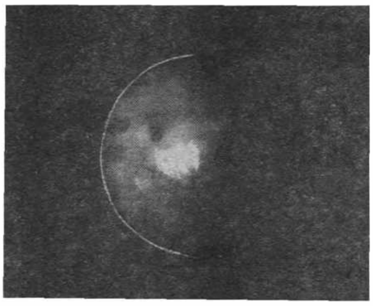
The philosopher and novelist, Olaf Stapledon (1886-1950) addressed the British Interplanetary Society on October 9, 1948 on the subject "Interplanetary Man?" (his text is presented in the November 1948 *JBIS*, p.213-233). Forty years later the substance of his remarks is remarkably fresh, and the discussion afterwards - among Stapledon, Arthur C. Clarke, R.A. Smith and others - is lively. Stapledon looked at how humans might go about colonising the planets: terraforming Mars, the Moon and Venus were discussed along with the complementary approach of eugenical adaptation of humans to fit planetary environments. But the principal emphases of his address where why we might undertake the colonisation of the planets and how these motives should relate to our fundamental values.

Space communities need not be limited to planetary habitats. A vigorous line of investigation has been pursued by Dr. Gerard K. O'Neill and others concerning establishment of space colonies in artificial stations, placed at a dynamically favoured location such as a Lagrangian point in the Earth-Moon system. In *The High Frontier* (William Morrow, 1977), O'Neill envisages an initial station with 10,000 inhabitants, supporting themselves through the generation of solar-derived power for use on Earth and obtaining much of the structural material for the station from the surface of the Moon.

Far-ranging space communities are embodied in the idea of a "world ship" - a self-sufficient vehicle which cruises interstellar or intergalactic space. A dramatic concept, extensively treated in fiction (Robert A. Heinlein's 1941 story "Universe," is a classic example), the world ship has been technically analyzed as well; see the June 1984 issue of *JBIS*.

Although humans have not yet founded what could be called a space colony, the thought that other, more advanced races might have done so has led to some interesting conclusions about extraterrestrial life. The physicist Enrico Fermi (1901-1954) once asked the question "Where are they?", initiating a series of questions concerning why it is that the Galaxy, some ten thousand million years old, has not spawned

Voyager Approaches Neptune



On May 1, Voyager 2 will be 115 days away from its closest approach to the planet Neptune. Other Voyager 2 data follows:

DISTANCE TO NEPTUNE: 167,266,000 km
DISTANCE FROM EARTH: 4,283,436,000 km
HELIOCENTRIC VELOCITY: 18.895km per second*

Values are for 0800 GMT on May 1, 1989 (figures are approximate).
* Velocity of the spacecraft relative to the Sun.

This image of Neptune was taken by Voyager 2 on January 23, when the spacecraft was about 309 million kilometres from the planet. A bright cloud feature is visible near the centre of Neptune's disc *NASA/JPL*

species which have overrun our solar system and planet.

Numerous theories have been devised: there is no intelligent extraterrestrial life; the solar system has been quarantined by extraterrestrials ("the zoo hypothesis"); interstellar flight is difficult or unpopular; or evolution occurring during migration removes extraterrestrials from our epistemological domain. The last has some appealing properties, and I have treated it in may paper, "Human Evolution in the Age of the Intelligent Machine" (*Interdisciplinary Science Reviews,* December 1983, p.307-319). In that paper the possibility of dominant hybrid organisms, "hyborgs" synthesized from humans and computers, arising sometime in the next 100 to 100,000 years is examined. Postulating a similar evolutionary phase for all planetary-originating life, the time scale for substantive evolutionary change may be sufficiently short compared to that required for interstellar migration to preclude the arrival of hominids, "little green men", at our doorsteps.

Does history have anything to teach us concerning the future colonisation of space? Although we may not be able to forecast the engineering details and the chronology of events, might not the constraints of human nature and past behaviour serve as a guide? Stapledon developed a future history which covered the entire span of the universe! More modestly, Heinlein has strung many of his works of fiction on a future history scheme spanning several centuries.

But I wish to speak more of the lore of the professional historian than the products of the writer of fiction. Implicit in the query is the assumption that the time scale which we consider here is short enough to preclude significant variation of human nature through evolution; a few thousand years might be a good number to hold in mind.

Frederick Jackson Turner (1861-1932) read his essay, "The Significance of the Frontier in American History", at the 1893 meeting of the American Historical Association in Chicago. His thesis was developed in a series of books over the next few decades and rests upon two basic points: (1) the frontier is the moving boundary between settled regions and an area of free land, into which new settlers continually expand, and (2) the frontier is the fundamental agent which shapes the character of the larger society of which it is a part. That is, Turner claimed that the frontier explained American development.

The phenomenon of the American frontier is conventionally placed in the period between the English settlement of Jamestown in 1607 and the official recognition in 1890 by the Superintendent of the Census of the loss of the frontier line. There were natural geographic features in the continent that prompted a series of semistable frontier lines in the westward march: the Allegheny Mountains, the Mississippi River, the Great Plains, the Rocky Mountains, etc. In addition to the multiplicity of a temporal succession of frontiers, lines drawn at any one time would differ depending upon whether one were considering the expansion of trapper, trader, cattle raiser, or farmer.

Turner saw the effects of the frontier process upon American development manifesting themselves in several ways but none more important than their influence upon democratic institutions. The individualism inherent in pursuit of frontier life and the waves of change generated by an expanding societal boundary constituted an inimical setting for authoritarian institutions.

The young historian Turner caught the academic world by surprise, and he followed up his advantage so well that serious attacks upon his new orthodoxy were not mounted until the 1920s. Criticism focused upon the lack of Turner's recognition of the importance of European influences and the elements of urban economics. Also, it was asserted that other frontiers - in South America, Australia and Asia - had to be considered in testing the hypothesis of frontier influence; the American experience was only a small piece of a larger stage of historical change. (In one generalization, Walter Prescott Webb moved the start of the frontier period 100 years earlier, to the discovery of the New World, and investigated the economic effects of this larger domain upon European society. See his book, *The Great Frontier,* Houghton Mifflin, 1952.)

The residuum of Turner's work is a heightened perception of the importance of the frontier for historical evaluations, but historians will argue about the relative weight to be assigned to the frontier factor in the scheme of overall development.

The anticipated colonization of space would seem to have some resemblances to frontier theory, and I will draw out the analogy by presenting a particular thesis, only one of many that are possible.

1. The space frontier will be the moving boundary between settled regions and a volume of free space into which new settlers will continually expand.
2. The space frontier will be the fundamental agent which shapes the character of Earth and its attendant settlements.
3. The primary material effect of the space frontier will be the technological progress which its movement stimulates.
4. The primary nonmaterial effect of the space frontier will be the attitudes, of mythic proportions, which it generates with respect to the value of individual effort and of peaceful cooperation among nations.

The first two points might be labelled "the strong hypothesis" of the space frontier. The purpose of the preceding discussion was to give them some credence by exposing a vein of thought which celebrates the importance of the frontier in historical development. Of course, not only Turner's original thesis but also the aptness of the space-to-Earth analogy can be questioned. Without attempting to mount a detailed, and lengthy, argument about the validity of the analogy, I will content myself with the observation that common usage, through the term "space frontier", endorses a resemblance.

Just as Turner identified several frontiers existing at the same time, we would expect more than one space frontier to be operative. In fact, the multiplicity of frontiers is even now evident if we delineate the domains of communications satellites, planetary landers, planetary orbiters, planetary flybys, etc.

The third point does not imply that economic benefits obtained through mining, farming, power generation, and population relief will not be of economic benefit. The judgement comes from noting the exponential growth of technology and its positive correlation with the opening of new space frontiers. The third point also looks ahead to a time when accumulated technological change may have fundamentally altered the human condition, i.e., the thesis, if vigorously interpreted, leans toward the epistemological solution to "where are they?" (It is also consistent with several other solutions.)

Point four relates to Turner, through its emphasis on individualism, but also touches upon Stapledon's assertion that we must look to our own values as well as our engineering.

One might question the inclusion of individualism in an enterprise so firmly wedded to government and corporate support. However, this support focuses on technological and financial needs. Atop this infrastructure is a corps of individuals, among the general public and the space agencies, who are moved by the great spirit of adventure inherent in the exploration of space; try to watch Voyager encounter Neptune for the first time this August without a shiver of emotion.

The addition of "peaceful cooperation" to point four could be considered as wishful thinking, and perhaps it is. Certainly international cooperation was not a dominant factor in the evolution of the frontier on the North American continent (the history of arctic and antarctic exploration is somewhat more favourable). But the technological and financial challenges of space flight for a single nation, plus some favourable trends that have already been established, provide plausibility to this part of the thesis.

Finally, the phrase "mythic proportions" in point four is chosen with care. "Mythic" is not identified with the pejorative sense of "false". Instead, it signifies a potent belief which arises from our human biological and cultural roots. Joseph Campbell (1904-1987), in his *Myths to Live By* (Viking, 1972), sees the Apollo Moon walks as the start of a new, unifying force for our age.

Human nature functions at many levels. I usually write this column at home by a window that faces east. On nights when the full Moon rises, it always catches my attention: as a source of illumination, as a place where 20 years ago I helped send men, and as a symbol for stirring dim beliefs that go back to the Old Stone Age.

Krakatoan-Class Volcanos

The uninhabited volcanic island of Krakatoa, in the Sunda Strait of Indonesia, blew apart in 1883. The awesome power of the release resulted in a 15m tidal wave and the deaths of over 30,000 people. Atmospheric effects, such as evinced by red sunsets and blue moons, were noticeable for years. A few tens of volcanic eruptions take place each year on Earth, but explosions with the force of Krakatoa are rare. Teams of investigators have been collecting data from a variety of sources, scientific and cultural, to identify, date accurately, and assess the human impact of large volcanic events within historical times. Dr. Kevin Pang of JPL and his colleagues are utilising ancient Chinese historical records to correlate societal effects with scientific measurements.

In a volcanic explosion, silicate ash is released into the atmosphere and can cause darkened days and ugly precipitates for a time, but the longer lasting effects of the event are due to gas releases. Sulphur dioxide combines with water in the atmosphere to form sulphuric acid droplets, and a significant amount of this compound is stored in the stratosphere as "dry fog". The phenomenon of dry fog was explained by the statesman and scientist Benjamin Franklin in conjunction with the eruption of Iceland's Laki volcano in 1783.

Suspended in the form of aerosol in the relatively quiescent stratosphere, above most weather, dry fog from a Krakatoan-class explosion can lower temperatures on Earth by a few degrees and affect the weather for years. The blocking of sunlight by the dry fog is particularly effective due to the large surface area presented by the legion of acid droplets. It also provides us with information about the volcanic event after being deposited in long-lasting snows such as those which blanket Greenland.

This information is encoded into the ice sheet in physical and chemical form. When a longitudinal cross section of an ice core is viewed under a microscope in polarised light, the annual layers of snow fall are distinguishable, much in the way that growth rings in trees can serve as dating devices, but counting the layers becomes more difficult at greater ages and depths because of distortion and flowing of ice under pressure. Depths of historical interest often involve a kilometre of overlying ice. Chemical measurements of the acidity of the ice-core sample reveal local regions where dry fog - sulphuric acid - has been pressed between the annual snows. Comparison of acid peaks with the count of annual layers provides a date for a presumptive volcanic event.

Pang said that for each of six anomalies which he has investigated, historical evidence has corroborated the hypothesis of a volcanic eruption. Additionally, physical corroboration comes from radiocarbon dating of organic materials such as trees or seeds, when the volcanic site is known, and through dating of frost-damaged tree rings.

European historical records provide a window to the relatively recent past. For example, Plutarch mentions various dire consequences of the assassination of Julius Caesar on the Ides of March in 44 B.C., "...the obscuration of the Sun's rays. For during all that year its orb rose pale and without radiance." Another telltale indicator of the involvement of vulcanism comes from the description of a contemporary comet, that classical acolyte of doom, as being reddish in colour. Michael Rampino and Richard Stothers, of the Goddard Institute for Space Studies in New York, have studied the cluster of historical events during this period of time and conclude that multiple eruptions of Mt. Etna in Sicily during 44-42 B.C. are responsible.

Ice core samples spanning this period of time validate the occurrence of a series of volcanic incidents through several surges in acidic levels. In this case, the historical data are probably more accurate than the physical data, so the ice-core method can be calibrated.

But by far the largest treasure of historical data is located outside of Europe in Chinese and other oriental records. The earliest such records predate European archives, going back to 2000 B.C. or even earlier, and are written on bone fragments and tortoise shells (in earliest times), moving in subsequent eras to bamboo strips, silk cloth, and paper. The Etna eruptions were responsible for three years of failed grain harvests in China and an inflation of the price of grain by as much as 1400 % between 44 and 42 B.C. (Grain price increases and human death statistics dolorously supply two quantitative societal measures of a volcanic event's severity.)

Pang and his colleagues at JPL, Santosh Srivastava and Dharam Ahluwalia, have joined forces with Professor Hung-hsiang Chou of UCLA's Department of East Asian Languages and Cultures to sift through oriental, especially Chinese, records, which have become more accessible in the last ten years. The intent of these investigators is to use oriental historical data, along with ice-core samples and tree-ring records, to refine and extend earlier researches based upon European records.

The Hekla 3 eruption in Iceland was 50 times the strength of Krakatoa and took place somewhere within 1159 to 1140 B.C., according to tree-ring data. (Trees in Europe show frost damage, reflected in the record of the rings. Hekla 1 and Hekla 2 were prehistoric eruptions, evidenced only be ice-core data.) Ice-core estimates of the chronology yield 1120 ± 50 B.C. for the explosion.

When Pang and his colleagues examined Chinese records for correlated events, they found extensive evidence manifested in a series of natural disasters. "In the summer of the fifth year of King Chou it rained dust at Bo". Snow in summer, over a foot deep, was reported. Agricultural consequences were present: "Frosts killed five cereal crops. Fiber crops failed. Heavy rainfall. The grain crops did not crow". From the historical evidence, they place Hekla 3 in the late 12th century B.C.

Certain worldwide events in the 6th century A.D. have been traced to the eruption of Mt. Rabaul on the island of New Britain in Papua New Guinea. Several European reports of a dimmed Sun correlate well with ice-core measurements (512-550) and tree-ring data (536-545). When Pang went to Chinese records he found summer snowfalls, crop failures, and major famines in this period of time. In fact, north of the Yellow River, where the short growing season increases human vulnerability to crop failures, 70 to 80% of the populace perished. The historical data yield a date for the eruption more precise than the physical evidence: 536-538.

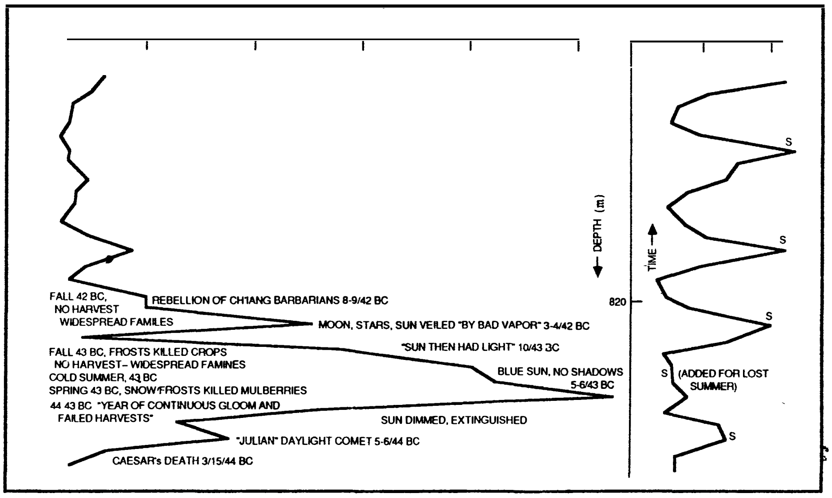
Using ice-core data and historical records, three other major volcanic events have been investigated by the JPL/UCLA team: a volcano of unknown location in Iceland (c. 209 B.C.), a volcano of unknown location (c. 269 B.C.), and the volcano on the Greek Island of Santorini (Thera): c. 1600 B.C.

The last volcano could have been a factor in the destruction of the Minoan civilisation and is currently under intensive investigation by Pang and his group in order to provide a reliable date: 1600 B.C. is their best estimate at present.

Inscribed tortoise shells from ancient China and kilometre-deep ice cores from Greenland have been linked in a most impressive web of interdisciplinary deductions.

"Dry Fog" (sulfuric acid) created by volcanic action and precipitated in Greenland becomes buried by annual snows and when retrieved by ice-core techniques serves as a source for dating large volcanic eruptions. The fluctuating line on the left measures the acidity of the ice-core and correlates with historical volcanic-like effects obtained from European and Chinese records. The nearly periodic line on the right is also derived from chemical analyses and provides a yearly chronology for the ice-core as a function of depth; the peaks labelled 'S' represent summers.

NASA/JPL



SATELLITE DIGEST -221

Robert D. Christy

Continued from the April 1989 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1979, 1988-101A, 19647

Launched: 0140, 18 November 1988 from Tyuratam, by F-1.
Spacecraft data: Cylindrical, probably about 7 m long and 2 m in diameter, equipped with solar cell panels and with a mass around 5,000 kg.
Mission: Electronic intelligence gathering over ocean areas.
Orbit: 403 x 417 km, 92.78 min, 65.03 deg, maintained by a low thrust motor during the operational lifetime.

COSMOS 1980, 1988-102A, 19649

Launched: 1500, 23 November 1988 from Tyuratam, by J-1.
Spacecraft Data: Not available, but the mass may be around 10 tonnes.
Mission: Electronic intelligence gathering.
Orbit: 849 x 854 km, 102.00 min, 71.01 deg.

COSMOS 1981, 1988-103A, 19651

Launched: 1450, 24 November 1988 from Plesetsk by A-2.
Spacecraft Data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, recovered after 14 days.
Orbit: 227 x 272 km, 89.49 min, 62.83 deg.

SOYUZ-TM 7, 1988-104A, 19660

Launched: 1550*, 26 November 1988 from Tyuratam by A-2.
Spacecraft data: Near-spherical orbital compartment carrying a rendezvous radar tower, conical re-entry module and cylindrical instrument unit with a pair of solar panels, and containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried Soviet/French crew of Aleksandr Volkov, Sergei Krikalyov and Jean-Loup Chretien (France) to Mir. Docking with Kvant's rear port occurred at 1716 on 28 November. Chretien returned to Earth in Soyuz-TM 6, along with Mir long-stay crew members Titov and Manarov. They landed at 0957 on 21 December. At 0931 the same day, with Volkov, Krikalyov and Poliakov aboard, Soyuz-TM 7 undocked and re-docked at Mir's forward port some 20 minutes later.
Orbit: Initially 194 x 235 km, 88.73 min, 51.61 deg then by way of a 256 x 291 km transfer orbit to a docking with Mir in an orbit of 337 x 369 km, 91.55 min, 51.63 deg.

COSMOS 1982, 1988-105A, 19662

Launched: 0900, 30 November 1988 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 356 x 406 km, 92.20 min, 70.01 deg.

STS-27, 1988-106A, 19670

Launched: 1431*, 2 December 1988 from Pad 39B, Kennedy Space Center.
Spacecraft data: Shuttle Orbiter 'Atlantis'.
Mission: Carried crew of Gibson, Gardner, Ross, Shepherd and Mullane. A primary mission objective was to launch the 'Lacrosse' military satellite. 'Atlantis' landed at Edwards AFB at 2336, 6 December 1988.
Orbit: 444 x 451 km, 93.51 min, 56.99 deg.

LACROSSE, 1988-106B, 19671

Launched: 2130*, 2 December 1988 from the payload bay of 'Atlantis'.
Spacecraft data: not available.
Mission: Military satellite, returning images of the ground, obtained via a radar system.
Orbit: 667 x 692 km, 98.32 min, 56.97 deg.

COSMOS 1983, 1988-107A, 19672

Launched: 1450, 8 December 1988 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 200 x 254 km, 89.04 min, 62.83 deg.

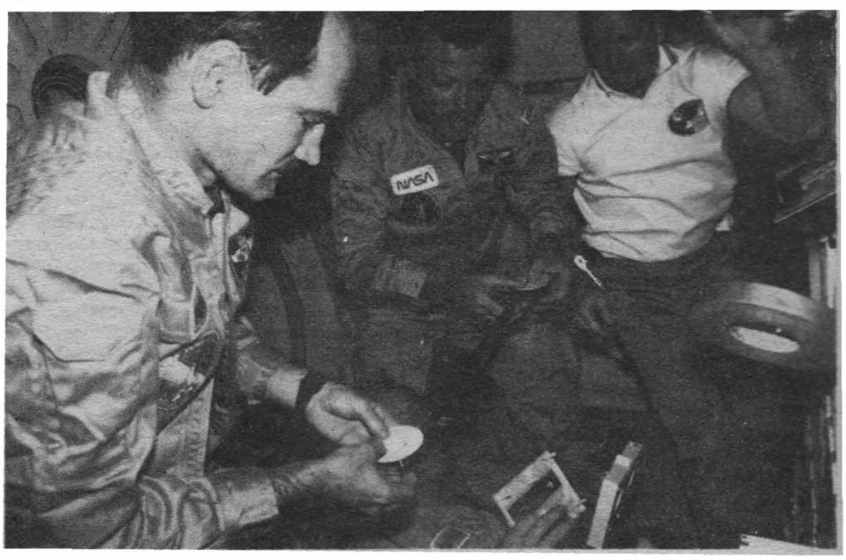
EKRAN 19, 1988-108A, 19683

Launched: 1150, 10 December 1988 from Tyuratam by D-1-e.
Spacecraft data: Stepped cylinder with an aerial array in the form of a 6 m x 2 m rectangular panel at one end. Electrical power is provided by a pair of rotatable, boom mounted solar panels at the opposite end of the body, and positioned at right angles to it. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing television and radio services to community aerials in remote areas of the USSR.
Orbit: Geosynchronous above 99 degrees east longitude.

SKYNET 4B, 1988-109A, 19687

Launched. 0033*, 11 December 1988 from Kourou by Ariane 44LP
Spacecraft data: Three-axis stabilised, box-shaped body, 2.1 x 1.9 x 1.4 m, with an aerial array on one face. Power is provided by a 16 m span solar array. The mass (in orbit) is 790 kg.
Mission: Military communications satellite.
Orbit: Geosynchronous above 1 degree west longitude.

NASA has released photos from the STS-27 shuttle mission, a military flight. Four of the mission's five crewmembers attempt to repair a video cassette in the mid-deck of the Earth-orbiting Atlantis. Left to right Guy S. Gardner, Jerry L Ross (partially obscured at bottom), Robert L Gibson amd William N. Shepherd The cassette contains video of the tile damage survey recorded by Atlantis' TV cameras



Ariane 4 Scores Another Success

The 29th Ariane blasted off from Kourou on March 6 carrying the first European operational weather satellite, Meteosat (MOP-1), and the first Japanese telecommunications satellite, JCSAT-1.

Ariane V29 was delayed three times. The launch, originally scheduled for February 28, was first postponed because of a strike by technicians working for the Thomson Company at the Guiana Space Centre. The dispute was resolved and the launch reset for March 4. But the countdown was halted three hours before lift-off when two umbilicals used to circulate air around the payload were pulled loose in a strong wind. The launch was rescheduled for the next day - but was delayed again, awaiting a spare part which was being flown to Kourou from France.

The Ariane was finally launched at 23:29 GMT on March 6 from the ELA-2 launch pad. The vehicle was an Ariane 44LP, equipped with two liquid and two solid propellant strap-on boosters. One minute six seconds after blast-off the solid propellant boosters separated. They were followed 1 minute and 23 seconds later by the liquid boosters. The first and second stages separated without incident. The Ariane's cryogenic third stage was ignited 5 minutes 47.8 seconds after launch and reached geostationary transfer orbit at T+17 minutes 41.7 seconds.

Parameters for the orbit at injection were:

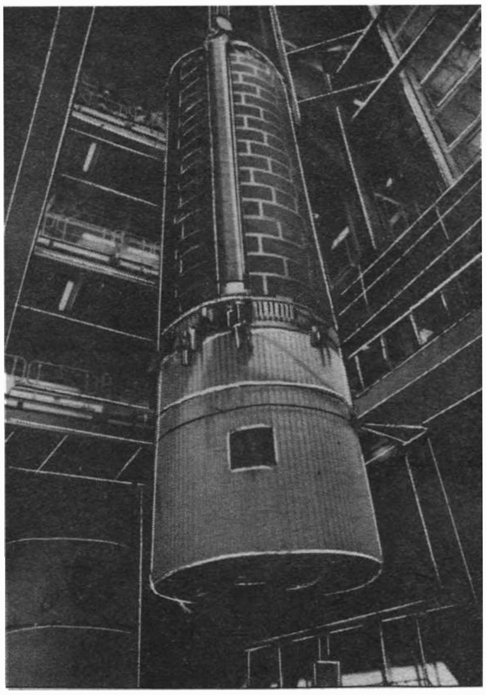
Perigee: 198.6 km (± 1km) for 200km intended

Apogee: 35,901 km (± 100km) for 36,060 km intended

Inclination: 7.04 (± 0.005) degrees for 7 degrees intended

Twenty minutes and 12.3 seconds after launch the JCSAT-1 separated followed by MOP-1 four minutes later.

• Arianespace has won the contract to launch the Japanese BS-2x direct broadcast satellite for the NHK company. The satellite will be placed into geostationary transfer orbit in December 1989 on an Ariane 44L, equipped with four liquid propellant strap-on boosters.



The Ariane V29 third stage is moved into position in the Vertical Assembly Building. The 2nd stage is visible in the background. *Arianespace*

MOP-1

MOP-1 (Meteosat Operational Programme-1) is Europe's first operational meteorological satellite. It follows three pre-operational satellites, launched by ESA, which have successfully displayed the capabilities of meteorological satellites:

• Meteosat 1 - launched in November 1977, by Delta from Cape Canaveral. The satellite provided data until its failure at the end of 1979.

• Meteosat 2 - launched by the third Ariane in June 1981 to replace its predecessor. The satellite is still operational and plays the role of Meteosat 3 back-up. The satellite will soon be deorbited as it is running out of fuel after seven and a half years of service.

• Meteosat 3 - launched by the first Ariane 4 in June 1988 to bridge a gap between the aging Meteosat and the first MOP spacecraft. Today, it provides the data used daily by weather forcasters.

The MOP-1 is the first of three satellites that will serve the meteorological community until the end of 1995. MOP-2 will be launched in 1990 followed by MOP-3 during the 1992-1994 period. All three MOP satellites are to be placed in geostationary orbit above the intersection between the Equator and the Greenwich meridian.

The primary task of the satellites is to produce cloud images every half hour, day and night. These images are transmitted in near real time to user stations located in Europe, Africa and elsewhere. There are over one thousand registered users, including national meteorological services, universities, commercial enterprises, schools and many amateur enthusiasts.

Cloud track winds, top cloud height and sea surface temperature can all be determined from MOP images.

The MOP satellites were designed by ESA, built by Aerospatiale and are operated by the Eumetsat organisation, representing 16 European nations.

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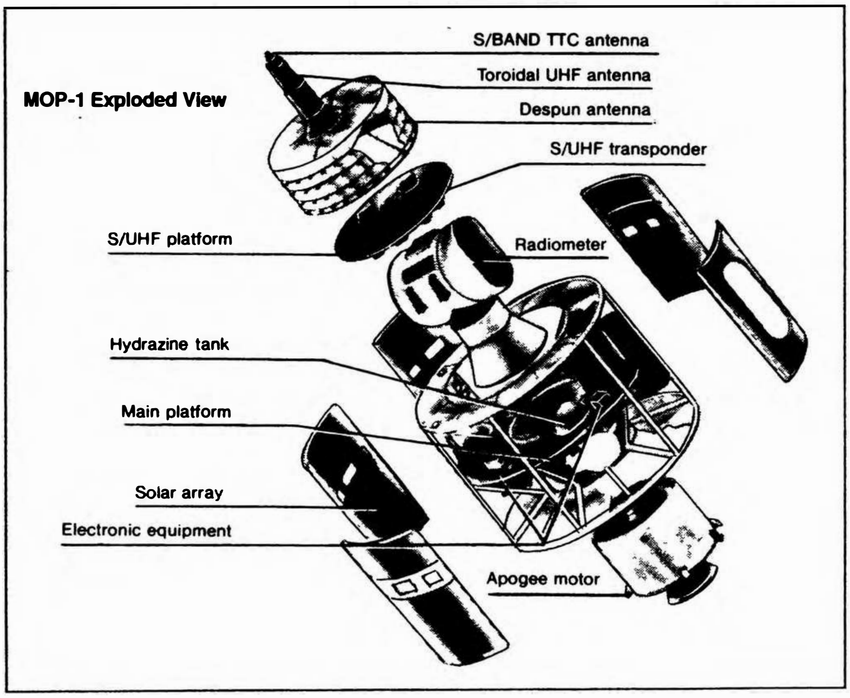

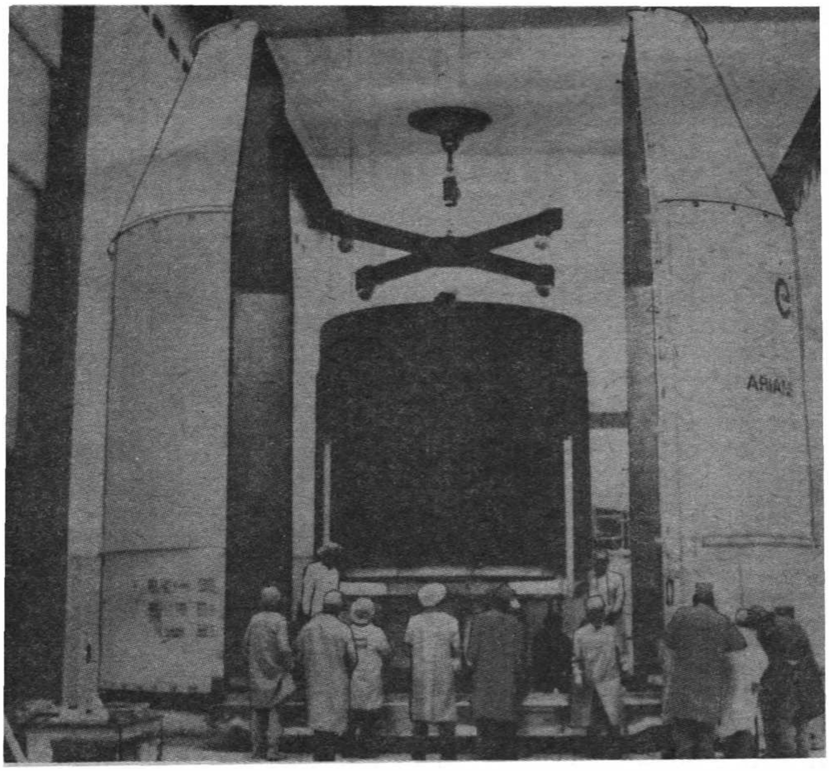

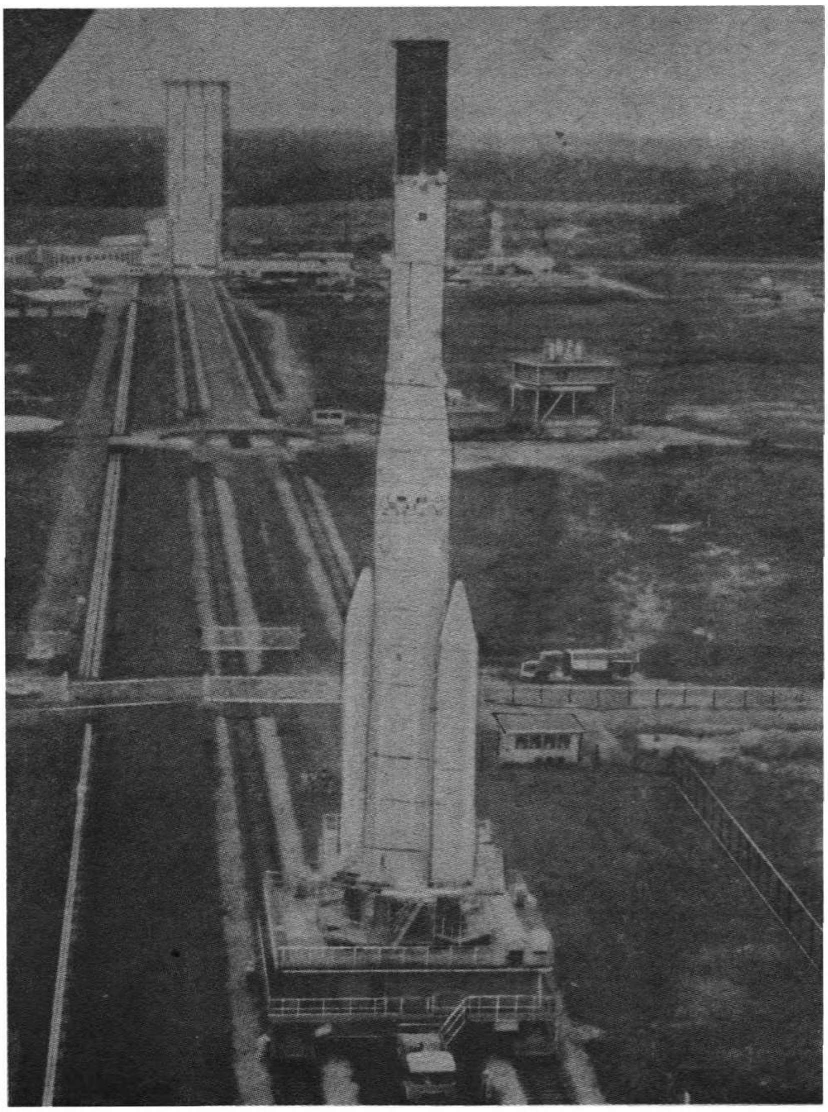

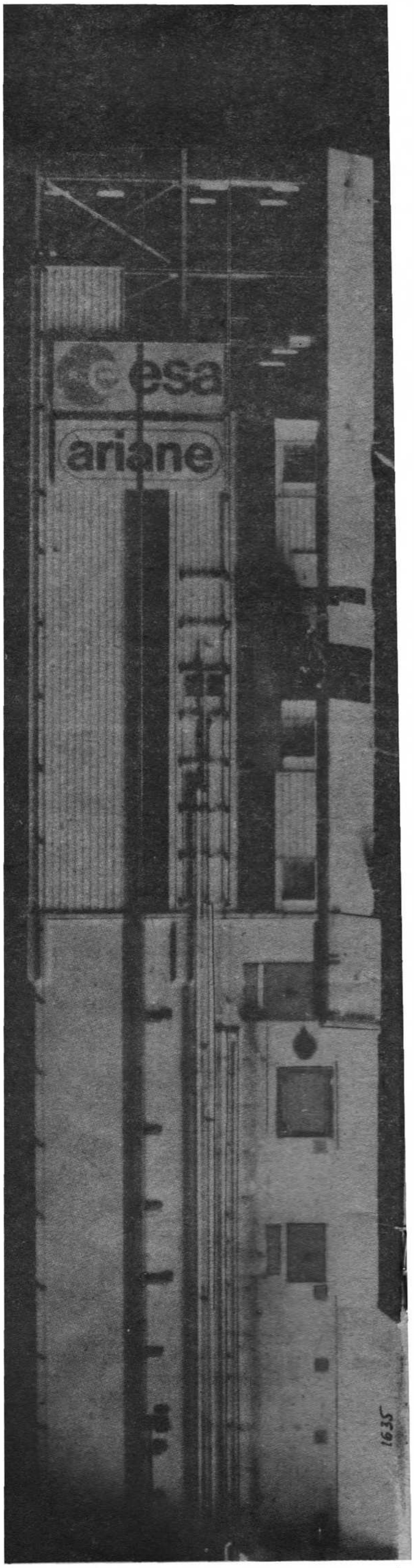
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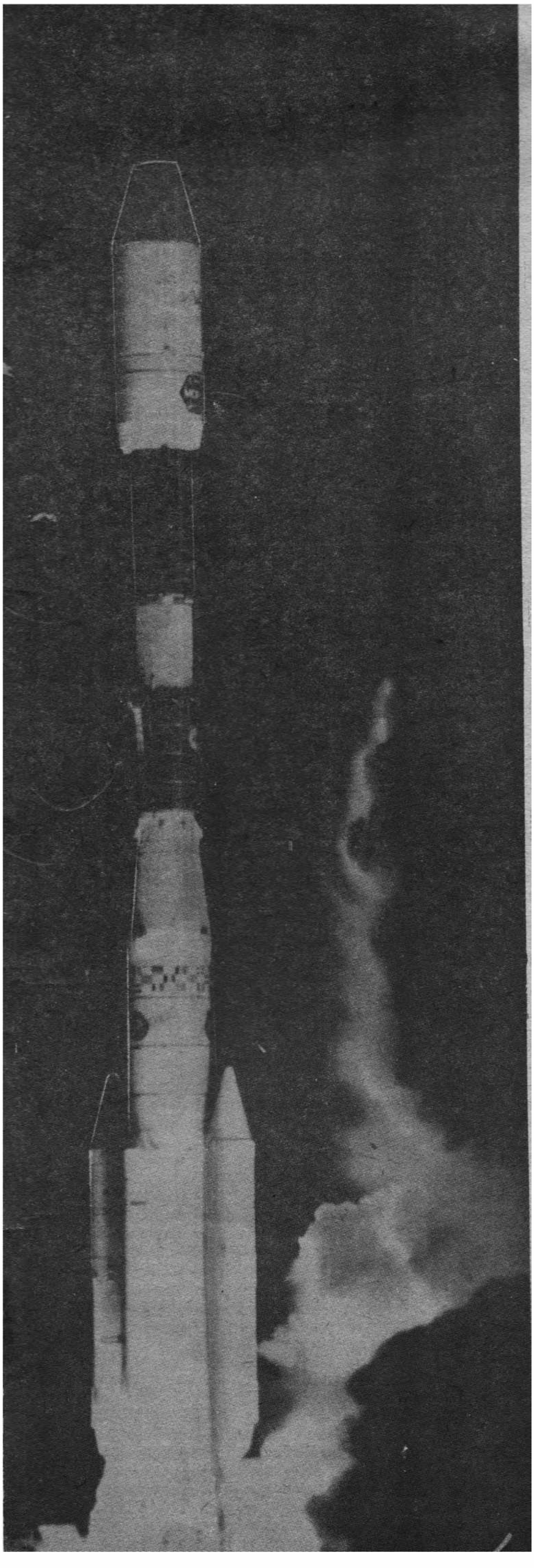

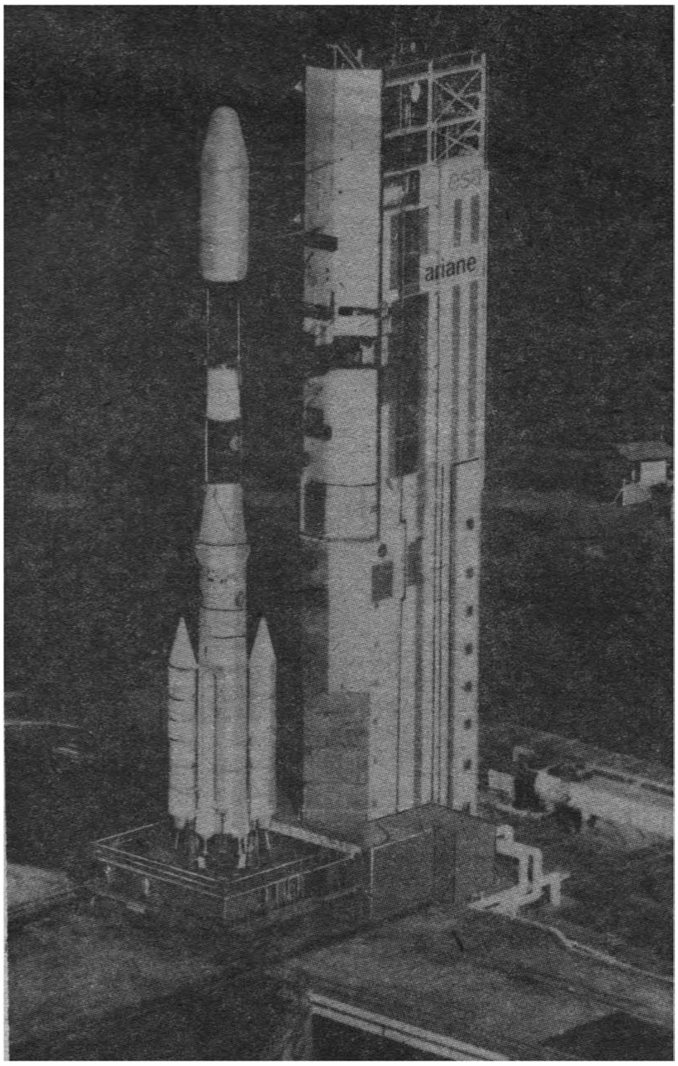
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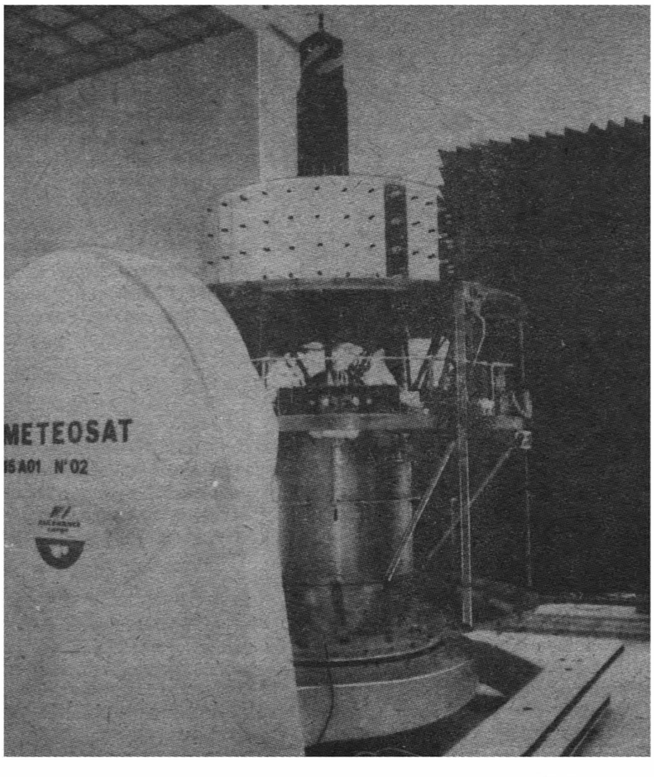
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JCSAT-1

JCSAT-1 is the first of two HS 393 satellites to be built for the Japanese Communications Satellite Company (JCSAT) by the Space and Communications Group of the Hughes Aircraft Company. The HS 393 is a larger, more powerful version of the Hughes HS 376 satellite and incorporates technology used for the Intelsat VI.

JCSAT is a joint venture between C.Itoh & Co. Ltd., Mitsui & Co. Ltd. and Hughes Communications Inc. This is the first time an American company has shared as an equity partner in a Japanese commercial satellite business venture.

Fully deployed, JCSAT-1 measures 10 metres in height and 3.66 metres in diameter. Its 2.4 metre antenna and multihorn feed array will produce a shaped beam on the contour of the four Japanese main islands and Okinawa, providing a signal strength of 50 dBW.

JCSAT-1 is stationed at 150 degrees east and is expected to have a life time in excess of ten years.

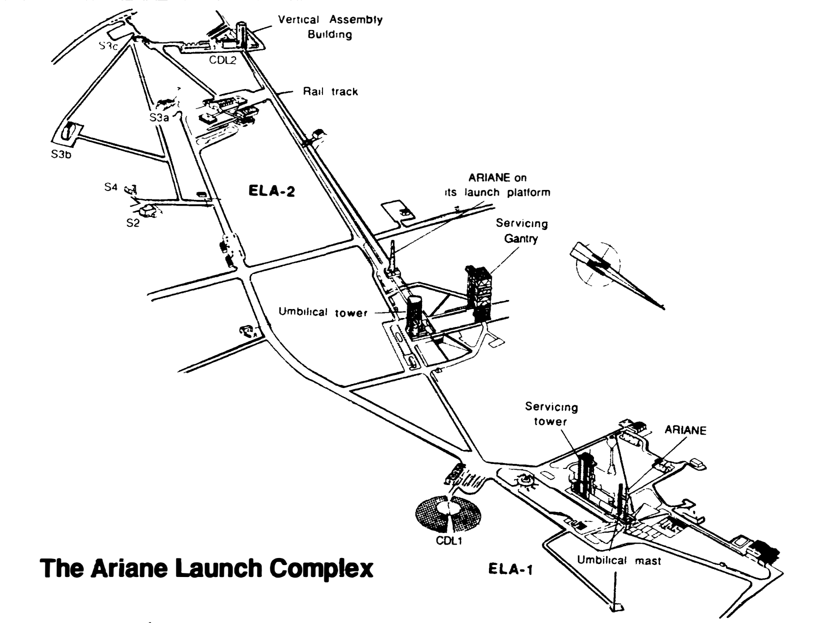
Kourou - The Jungle Space Centre

Ariane launches are made from the Guiana Space Centre (CSG) near Kourou, in the South American state of French Guiana. The Guiana Space Centre was set up by the French Government in April 1964 and built by the French space agency, CNES. It became operational in April 1968 with the launch of the Veronique sounding rocket. Following the Diamant programme and the Europa project, the CSG has been used for Ariane launch operations.

The CSG facilities are spread over an 18 km strip of the Atlantic coast between Kourou, which used to be a small fishing village, and Sinnamary, a sleepy river crossing.

Located 5.3 degrees north of the Equator, the CSG is ideally suited for the launch of satellites into geostationary orbit. The Centre's proximity to the Equator makes it possible to send into orbit, at an equal cost, a payload 17% heavier than the equivalent launched from Cape Canaveral. The reason for this increased performance is the rotation of the Earth from west to east - the rotation increases to maximum velocity at the Equator. Consequently at the Equator 6% of the velocity required to place a payload in orbit is free.

There are two Ariane launch pads, ELA-1 and ELA-2 (French translation - Ensembles de Lancement Ariane).



The Ariane Launch Complex

ELA-2

ELA-2 is for the launch of Ariane 2, 3 and 4 vehicles, it was first used in March 1986. The launch complex consists of two parts - the preparation area and the launch zone - linked by a rail track 1 km long. At the start of the rail track is the 80 metre high Vertical Assembly Building. Inside this building the Ariane vehicle is assembled upon a mobile launch platform. The strap-on solid propellant boosters are attached to the Ariane at the launched pad to minimize the risk of accidental ignition. It is also considered safer to attach the payload fairing, containing the satellites, after the launcher has arrived on the pad. This operation is usually conducted about five days before blast-off.

Once stacking and checkouts in the assembly building have been completed (in the case of an Ariane 4 this usually takes about a month) the vehicle is hauled to the launch pad along the rail track by a powerful truck. Weather conditions for the 45 minute journey are carefully monitored - a strong wind could topple the launcher. Once the assembly building is vacated, stacking of the next Ariane can begin.

At the pad, the Ariane is coupled to the 74 metre high umbilical tower, which provides fluid links between the launcher and the ground facilities. Two cryogenic arms extend to link up with the third stage of the vehicle.

The Ariane is then enclosed within a servicing gantry where final launch preparations can continue in a sheltered environment. The preparations include: assembly of the solid propellant boosters, final launcher checkout and assembly of the payload and fairing. Five and a half hours before launch the gantry is withdrawn to a safe distance.

(Top Left) JCSAT-1 is lowered between the two halves of the Ariane payload fairing.
(Bottom Left) Ariane V29 is towed to launch pad ELA-2. Note the payload fairing has not yet been attached. The Vertical Assembly Building can be seen in the background at the left. To the right of the Ariane stands a second mobile launch platform.
(Centre) Ariane V29 blasts off from pad ELA-2 on March 6.
(Top Right) An Ariane 4 stands poised for launch.
(Bottom Right) MOP-1 during prelaunch preparations.

ELA-1

ELA-1, used since December 1979, is designed for Ariane 1, 2 and 3 vehicles with a two month interval between launches. The ELA-1 complex differs from ELA-2 in that the Ariane assembly takes place on the launch pad. The stacking of the vehicle within a servicing tower takes approximately 10 days. Checkouts of the vehicle continue for 26 working days in the case of an Ariane 2 and 29 working days for an Ariane 3. The payload is placed atop the launcher about six days before launch.

The servicing tower that enclosed the vehicle is withdrawn on launch day, six hours five minutes before blast-off.

The ELA-1 launch pad will fall into disused when the final Ariane 3 takes to the sky, in June or July.

Payload Facilities

The Payload Preparation Complex (EPCU) is placed at the disposal of Arianespace customers for the preparation of their satellites from their arrival in Guiana up to the mounting of the payload on the Ariane launcher. Designed for the preparation of five satellites simultaneously, the EPCU consists of several buildings:

- Buildings S1A and S1B are located in the CSG Technical Centre, and provide clean-room facilities for satellite preparation.
- Buildings S2 and S4 located near the two ELAs, are designed for solid kick-motor preparation and X-ray operations.
- Buildings S3A and S3B, located near the two ELAs, are assigned to satellite propellant filling operations and final integration, assembly of the satellites on a Spelda or Sylda dual launch system, and final encapsulation into the Spelda/Sylda and the Ariane nose fairing.
- Building S3C is located close to S3A and S3B, and is used to monitor and control hazardous operations conducted in the latter.

A Way Forward for Britain?

A Philosophical Approach

Roy Gibson, former Director-General of the British National Space Centre, suggests a way forward for Britain in space. This article is based on a paper presented at the British Interplanetary Society's Space '88 meeting, held in Hastings last October.

I share the view that there is no point in harping on about the need for more U.K. Government funding for space. I sincerely believe that the Government made a serious mistake in not giving space a higher priority - I certainly have not changed my mind on that - but if the light is to dawn, it can only be through a rather complicated and lengthy process of self-persuasion, and not by any sniping, Minister-bashing, or still less by a head-on assault. I am hopeful for a gradual conversion - and to the extent that I can, still work for it. Since this is mainly a national occasion, I can afford to be a little recondite to saying "I resigned, but I am not resigned".

What can we do, to get the best out of the present situation?

Here at home, most of the necessary actions are easy to identify, and it is encouraging to see that some at least of them are being taken:

The British National Space Centre

Even though it has not been given control of the total U.K. spending on space, in the way we recommended, and although there has been only a very small increase in the money available, it is essential to keep the BNSC going and to encourage it to exercise a strong coordinating role wherever it can. Obviously this is a difficult task and the government's attitude encourages the participants, such as the SERC, NERC and even the Ministry of Defence, to set and pursue their own objectives with their own budget. BNSC could then quickly become just an arm of the Department of Trade and Industry. Ironically, this backtracking would come just at the time when other European governments are realizing the value of real intergovernmental coordination in space. Both the Germans and the Italians have created governmental space agencies, and the Norwegians have also reorganised themselves along these lines, too. Only in this way can a nation exercise any real influence over the European Space Agency - or indeed - in any other international body effecting space.

It was pleasing to see the appointment of Arthur Pryor to Head BNSC, for he has a fine reputation and this is an obvious demonstration that the post is still taken seriously.

To be realistic Arthur Pryor's BNSC

By Roy Gibson

will not have an easy task, but it is essential that everyone sees them as the centre for our space activities and - equally important - that they see themselves in the same light.

The Science Community

They seem to be surviving quite well, and they are still being solicited to join overseas groups in many parts of the world: a tribute to their competence and ingenuity. The crunch will come when the other 12 Members of ESA ask the U.K. to join them in increasing the mandatory science programme budget by five per-cent per annum for a second period of five years-starting with 1989. The U.K. has so far said "No" - and that with the finesse and politeness which have characterised our recent European decisions. The amount of money is relatively small, but SERC do not consider it to be on their priority list, and, with the continuation of this fragmented approach, no other government department is volunteering to foot the bill. The danger is not so much in the damage to the ESA Horizon 2000 science programme - although it will certainly have deleterious effects - but much more the thwarting of the ambitions of our 12 European partners. We really must either find some way of raising the money, or at least, a legal trick to allow the others to continue without us - not as simple as it may appear.*

The Private Sector

Well, most firms have taken a cold shower in the past 12 months, and it is not easy to persuade them to re-start initiatives unless they allow returns to be foreseen in the not too distant future. From the very start of the BNSC, this was our weakest link. Many companies helped enormously in producing the National Space Plan -the work they did then was really excellent - but the bigger boys never did like the idea of organizing a sort of trade association, along the lines of the French Prospace, to widen the industrial participation. A scheme to have a kind of bolt-on extension to BNSC, which would feed information and intelligence to the private sector, was nearly ready to get off the ground when the axe fell last year. It is still needed. Showing the interest and the commitment of large numbers of private companies, is one of the critical elements in persuading the government to release more funds.

* In the event the UK voted in favour of the increase for science at the meeting of the ESA Council in December - although this will probably have to come out of existing funds

Roy Gibson

Marriage between Universities and the Private Sector

Several of these have been arranged and I find this very encouraging. It is particularly rewarding when the university contribution is multi-disciplinary, because the future exploitation of space needs the skills of a great number of disciplines and faculties.

My Philosophy

Perhaps we can best characterise the present situation by saying that the bleeding caused by negative decisions has been staunched. The patient is understandably weak, but beginning to look around and take stock. British space is not dead, but I would still put it on this "seriously ill" list.

In describing my philosophy I would recommend taking note of the following: Changes of ministers, indeed changes of governments, will not in the next five years or so result in any significant increase in government investment in space. Furthermore, if I can play Cassandra, I believe that substantial cost increases in the ESA Hermes, Ariane 5 and Columbus programmes will be progressively revealed over the next few years, and that these will be used in the U.K. as a justification for our attitude at The Hague in 1987. This is likely to harden the government's attitude. Great regard though I have for ESA and its people, I consider that large increases in costs to completion are inevitable.

It will be tempting for ESA (and per-

haps for some national delegations) to conceal the worst news until the programmes have sufficient momentum to resist sudden stops - but, although it will make for a tough period, I am hopeful that ESA will have the courage to ferret out the facts and to make them public. In my view, the probability of cost increases is not a justification for the UK opting out; it will be a vindication for our proposed policy of keeping a major role in ESA and exerting influence from within.

Many ESA delegations regret our very much reduced role because no one has yet replaced us as the financial conscience of the Council.

But, so far as the size of our participation in these programmes is concerned, it is too late to change; I hope that, as money becomes liberated from completed projects, the UK will be spending it on becoming an intelligent user of other people's space infrastructure. It seems to me that there are three interesting areas of utilisation on which we should concentrate any space funding that becomes available:

Remote Sensing: An all-out attack on applications, giving the maximum incentive to the private sector to share in the investment - and to take their profit - even if it means modifying our traditional way of operating. This whole area of returns from Earth observation satellites needs a lot of new thinking. Building ERS 2, or even polar platform, is not an adequate substitute for a redefined national strategy.

Telecommunications: But, again, strictly directed towards new and predictable uses. We should be sceptical about flying new test beds and concentrate on the development of the new payloads which will be needed, not least by INTELSAT and Inmarsat. (Inmarsat, for example, is just about to announce to industry that it is starting the procurement process for the third generation of its satellites). And we should not ignore the vast markets available for the small, mobile terminals - against which the space segment looks commercially relatively uninteresting.

Space Station Experimentation: Perhaps smaller in its demand than the other two, it is - or will be - just as important. It is imperative that, in spite of many national prejudices against expenditure in this field, we put money into preparing to be regular and clever users of the new facilities being created largely by other people's money. When the time comes, they will be delighted to welcome us as customers. But this preparation for the Space Station era cannot happen spontaneously; it needs close coordination with industry and with universities not only in laboratory work but also in trying to take advantage of flight opportunities - not despising aircraft and sounding rockets, by the way. And above all, it requires 10 years of government seed funding; not large amounts, but a continued and assured flow to finance a carefully worked out programme, taking into account what others (notably the Germans and Japanese) are interested in and how they are organising themselves.

In my crisis philosophy there is room for Hotol, too - but a de-hotolised Hotol

In my crisis philosophy there is room for Hotol, too - but a de-hotolised Hotol. It is my perception that the longer term benefits of Hotol (X minutes to Sydney, etc) have in fact militated against obtaining government support for fear of implicating them in a large technological white elephant. The way ahead I see is in active stimulation of a three or four technological programme which would concentrate mainly on the development of new materials. In this way one could hope to harness the interest - and the funds -of the non-aerospace firms; particularly those who have their own motives for wanting to see new materials developed. I personally would favour making this an international effort, though at this stage outside the framework of ESA: they have enough on their plate. And I would also hope that some small contribution could come from BNSC, to enable them to have adequate visibility of the project.

There are, inevitably, industrial - I would almost say behaviourial-consequences of this change of emphasis. But, to do it successfully, it still needs a strong, central coordination from BNSC and the active participation of the private sector. I hope we have the resolve to achieve this change in attitude in the comparatively short time left to us. It would mean a lower profile for the UK; less glamorous work and, frankly, taking fourth or fifth place in the ESA pecking order, but if we are to salvage something out of the mistaken government policy, we must adapt to this new role. In so doing I hope that we can maintain our competence more or less intact in critical areas, and prepare ourselves to be ready to exploit the farsightedness and the financial investment of our European partners. Maybe we can do the same for them in a subsequent generation of space development.

There - you can't expect me to be much more philosophical than that!

On the Way to Horizon 2000

By Norman Longdon

The European Space Agency received a most welcome Christmas and New Year present when the ESA Council approved in principle the Long Term Plan. Thus the decision-making cycle which began at the Ministerial meeting in November 1987 in The Hague was completed.

For the ESA Scientific Programme, it was particularly rewarding that the level of resources for the mandatory programmes was approved unanimously. This will mean that the scientific budget will have an annual average increase of 5% up to 1992. The space science communities throughout Europe can therefore look forward to the very imaginative and forceful programme known as 'Horizon 2000' going ahead.

At the same time, the ESA Science Programme Committee made up its mind on the next medium-sized project to be undertaken within the scope of Horizon 2000.

There were five candidates from which the project could be chosen, and it is of interest to see the scope of modern space science with a quick review of all the candidates. Although strong support was given to all the candidates, funding being limited, work on only one project of this size could be started at present.

The five missions competing for selection were:

- Lyman, an Observatory covering the ultraviolet wavelength range, to be jointly procured by ESA/NASA and Canada
- Quasat, a very long baseline interferometry mission, also an ESA/NASA/Canada cooperation,
- GRASP, a gamma ray Observatory and
- VESTA, a joint ESA/CNES/USSR mission to the asteroids,
- CASSINI/Titan Probe, an ESA/NASA cooperative venture including a Saturn Orbiter, and a Titan Atmospheric Probe.

The prime objective of the Lyman mission would be the spectroscopic study of faint astronomical objects in the 90 to 120 mm segment of the ultraviolet spectrum - a region that is known to be extraordinarily rich in key atomic and molecular transitions, but which has only been briefly explored by previous astronomical space missions. Lyman would be a true international astronomical observatory facility that would address a wide span of astrophysical topics, ranging from the physics of the atmospheres of planets and stars, to reconstructing the history of element creation in our Galaxy and the Universe as a whole.

Quasat would be an Earth-orbiting radio antenna to be used in conjunction with ground-based Very-Long-Baseline Interferometry (VLBI) networks in Europe, the USA, the USSR and Australia to produce radio images at frequencies of 22, 5, 1.6 and 0.3 GHz. By combining simultaneous space and ground observations with baselines of up to 50,000 km, Quasat could provide radio images forty to two hundred

times sharper than those from Earth-based VLBI networks, and one hundred thousand times sharper than those from the Hubble Space Telescope. The reason for going into space would be to create interferometer baselines longer than the Earth's diameter and thereby achieve improved angular resolution. However, equally important would be the fact that images of much better quality could be obtained because the spacecraft's orbital motion would produce excellent coverage of the interferometer aperture plane. The scientific research conducted with Quasat would address such problems as the physics of the central region of quasars and active galaxies the distance scale and rate of expansion of the Universe, and star formation.

If chosen GRASP would have been the first genuine high-quality spectral imager designed to operate over a wide spectral range with a high sensitivityover the entire operational range for an observation period of 30 hours. Fundamental new astrophysical data would be revealed by this exploratory mission to investigate gamma-ray sources in what is basically an unexplored waveband for the first time with both high spectral and high spatial resolution.

The heavenly bodies that orbit the Sun are classified into two main categories: the planets and their satellites, and the so-called 'small bodies', namely asteroids and comets. The Vesta missions, named after one of the largest asteroids, were proposed as a trilateral cooperative endeavour by the European, French and Soviet space agencies (ESA, CNES and Interkosmos). Two identical space systems would be launched in 1996 and would visit up to eight small bodies, including one or two comets, over a five-year period.

The Vesta missions would pursue and extend the small-bodies exploration programme that began with the flybys of Comet Halley by the Giotto and Vega spacecraft. They would also be the forerunners of the ambitious Comet-Nucleus Sample-Return mission, Rosetta, planned for the turn of the century.

It is clear that each of these four proposals was an exciting prospect, but only one could be chosen and the decision was made in favour of the Cassini mission.

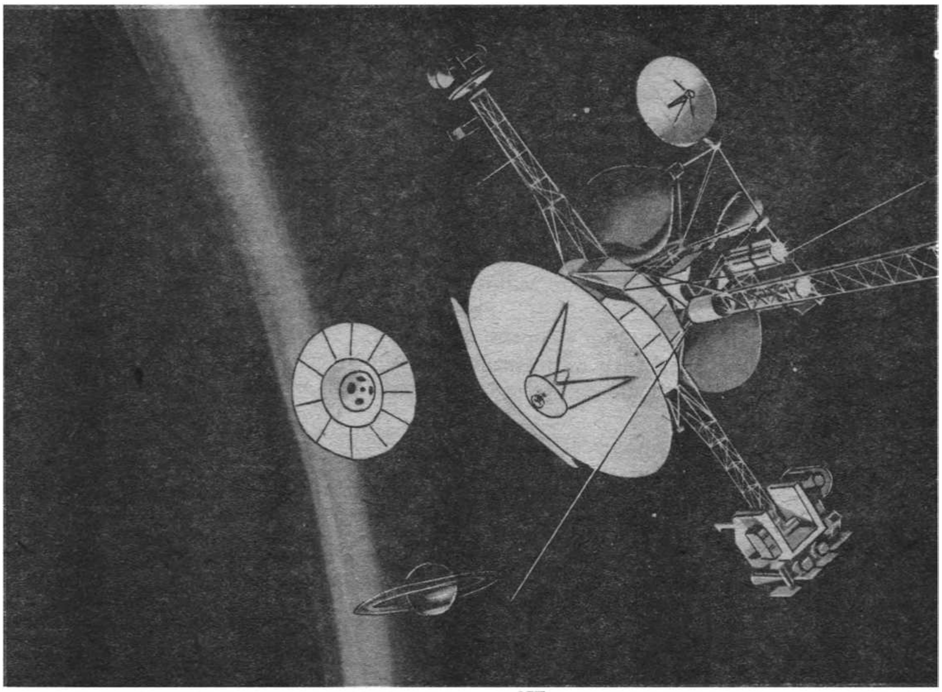
The unique scientific observations made by NASA's Pioneer and Voyager spacecraft yielded a wealth of information that has fundamentally changed our concepts of the Jovian, Saturnian and more recently Uranian systems in particular, and our view of the solar system as a whole.

A thorough exploration of the Jovian planetary system is the major objective of the Galileo mission, which consists of a Jupiter orbiter and an atmospheric probe, currently planned for launch in 1989.

The Cassini mission to the Saturnian system is the next logical step in the detailed systematic exploration of the outer solar system. Saturn's planet-sized moon Titan, with its intriguing atmospheric composition, is an especially interesting target.

The Cassini mission will consist of a Saturn Orbiter and Titan Atmospheric Probe, and is ideally suited to a joint venture. NASA will provide the Orbiter, launcher and Deep-Space Network for operations. ESA will provide the Titan Probe system and participate in the operations.

The Titan Probe has now been given a name: the Huygens Probe. It was the Dutch astronomer, Christiaan Huygens who discovered Titan in 1956. Present planning foresees a launch in April 1996.



Artists impression of Cassini and the Huygens probe above Titan.

The joint mission now awaits formal confirmation from NASA.

Horizon 2000 is built on four major 'cornerstones' of which the first - the Solar-terrestrial Science Programme (STSP), the ESA element of which is based on the SOHO and Cluster missions - is under way. SOHO, the Solar and Heliospheric Observatory, and 'Cluster', a four-spacecraft plasma-physics mission will attack outstanding scientific problems in solar, heliospheric and space-plasma physics through a unified and coordinated approach. Together they will address the major issues of the Sun-Earth relationship.

From the scientific side, the payload selection has been made. About 40 proposals were received, and investigated by a Joint ESA/NASA Evaluation Committee in combination with the ESA Programme Office. ESA and NASA jointly announced the payloads for both missions. Eleven instruments were selected for Cluster and twelve for SOHO.

The Cluster instrumentation is intended to cover a wide range of plasma parameters with high time and spatial resolution. With one exception, the instruments on all four Cluster spacecraft would be identical, instrument responses being an essential factor for the accurate determination of three dimensional features in geospace.

The instruments which were selected for SOHO should allow a coordinated approach to the main aims of the mission. Three instruments will be devoted to the study of the solar oscillations and the solar irradiance variations, for the understanding of the solar interior structure and dynamics. Six experiments consisting of telescopes, some with associated spectrometers will study the physical processes in the solar atmosphere in an attempt to understand the formation of the solar corona and the origin of the solar wind, and three groups of 'in situ' particle analyzing systems will study the composition of the resulting solar wind and energetic particles generated at the Sun.

Although their time is well into the future, early work on the other three cornerstones progresses.

The X-ray Multi-Mirror Mission (XMM) cornerstone should make a major step forward in x-ray astrophysics. It is planned as a unique mission in that it will have a very high energy collecting area due to the large number of nested x-ray reflecting mirrors, allowing it to observe to the edge of the known universe.

The Rosetta cornerstone, previously called CNSR (Comet Nucleus Sample Return) will have as its main task the return of a sample of cometary material to the Earth. Preliminary mission definition studies and preparation of the necessary technology are under way, the purpose being to define a mission concept acceptance to both ESA and NASA. Although nothing is finally settled the mission scenario foresees a launch in 2001, with the sample return some seven years later.

The Sub-Millimetre cornerstone would aim to provide Europe with a major space observatory for high throughput heterodyne spectroscopy in the 100 micron - 1 mm wavelength range; a range of wavelengths encompassing the last major window of the spectrum to be opened to scientific studies, it is considered of importance to the understanding of the processes of star formation and the determination of the rate of expansion of the Universe.

The on-going projects within Horizon 2000 include Hipparcos, the ESA elements of the Space Telescope, Ulysses and ISO (the Infrared Space Observatory). In some cases, of course, launch dates and associated events have been heavily influenced by the delay in the Shuttle programme. But with renewed confidence in the Shuttle, the manifests are being sorted out, and the project teams have definite goals to aim at.

The ESA scientific programme is broad in scope, demanding on the technologists as well as the scientists, and worthy of being counted as one of the major space exploratory programmes of the coming decades.

SKYNET 4
The Unknown Soldier

As far as the popular press were concerned, the launch of Ariane flight V27 on December 10 1988, was memorable for the launch of the Astra direct broadcast satellite. Few journalists stopped to realise that the Ariane 4 launch vehicle carried a co-passenger to Astra, Skynet 4B — a British military communications satellite. Few were even aware that Skynet 4B was the first military communications satellite to be launched by Ariane.

The Skynet story began as far back as the 1960s, when the MOD recognised the advantages of a satellite system to provide secure strategic and tactical communications to its armed forces stationed around the world. Actual involvement with military communications satellites started with the US Initial Defence Satellite Programme (IDSCP) which later led to the UK pioneering the use of geostationary communications satellite called Skynet 1. In 1974 a more capable Skynet 2 satellite was launched.

The Skynet 3 programme was cancelled after a change in government policy removed the requirement for communications to permanent garrison areas "east of Suez". Resulting reduced space segment requirements, with emphasis on NATO areas, were satisfied by arrangements within the alliance.

In the late 1970's advancements in technology permitted the development of a new range of tactical terminals whose deployment would be constrained by the limited space segment capacity. This led the MOD, in 1981, to proceed with a new generation of military communications satellites — Skynet 4. Three Skynet 4 satellites were ordered to provide military echelons ranging from major headquarters to individual army units, ships and aircraft with communications of unprecedented security, reliability and survivability. British Aerospace was selected as prime contractor with Marconi Space Systems as sub-contractor providing the communications payload.

Skynet 4B

The three-axis stabilised design of Skynet 4 was a major departure from the spin stabilised design of the Skynet 1 and 2 series of satellites. The spacecraft platform is derived from the well proven OTS/ECS platform originally developed by BAe for ESA. In all, thirteen satellites of this class have been built for civil use.

Weighing 1433 kg on launch (790 kg in GEO), Skynet 4 comprises a Service

By Neil Pattie

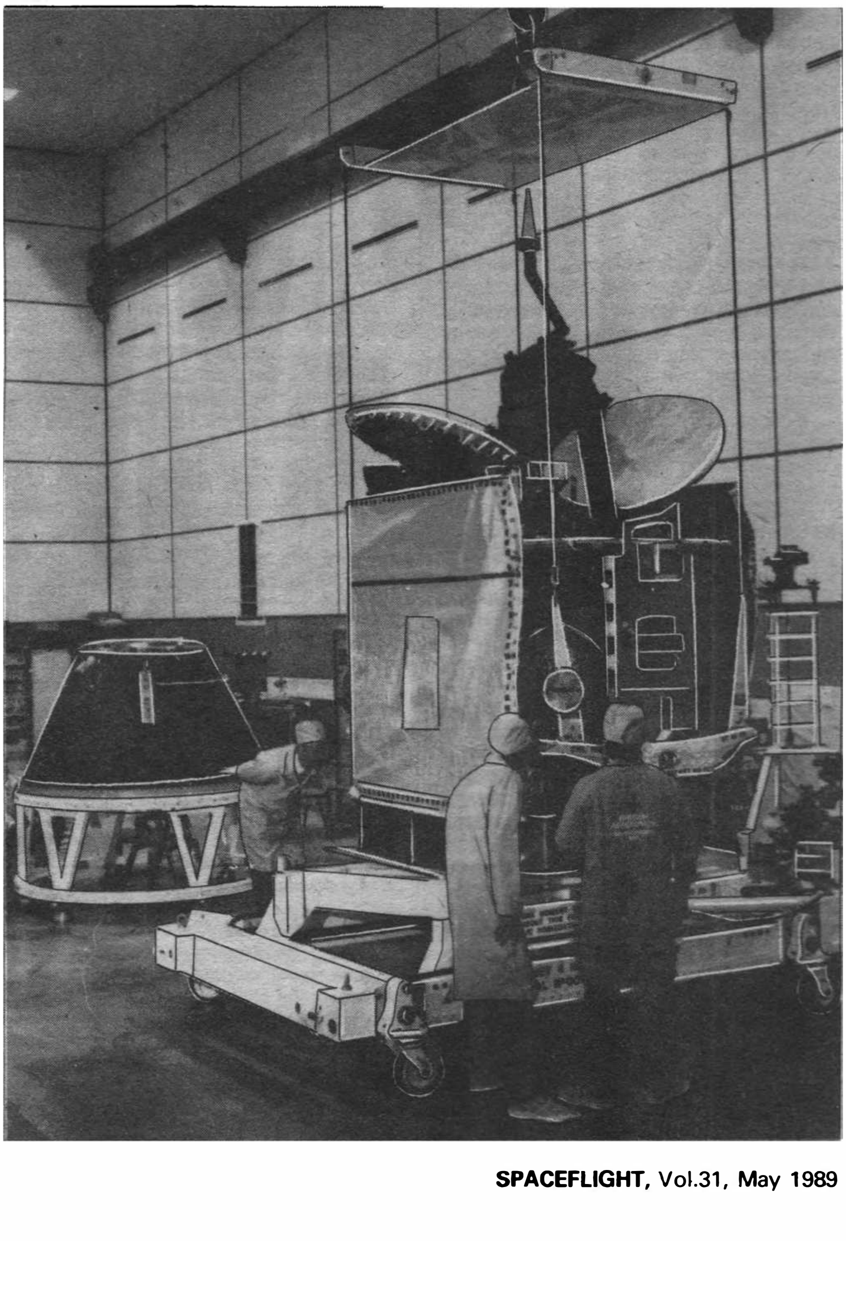
Module (SM) and Communications Module (CM). This arrangement enabled parallel manufacture of both modules at separate sites prior to integration. The SM, housing the central thrust cone and Apogee Boost Motor (ABM), also provides housekeeping and attitude and orbital control functions. The satellite's major structural elements are predominantly made of aluminium alloy honeycomb with aluminium or CFRP skins, glued together with epoxy resin.

Connected to the SM are two solar arrays supplying 1200 W at a regulated 42 V in sunlight. During eclipse periods, power is provided by two banks of rechargeable nickel cadmium batteries with an unregulated output between 30 and 37 V.

Thermal control is basically of a passive nature. The internal temperature of the satellite is carefully monitored and heaters are used to prevent the temperature of some units from falling to unacceptable levels. Secondary Surface Mirrors are mounted on the satellite's north and south faces and act as both good emitters and good reflectors of the sun's radiant heat and unwanted heat generated by the spacecraft's subsystems. Thermal blankets are also used to prevent heating by direct sunlight and to keep in wanted internally generated heat.

The CM is a 'U' shaped structure, a floor and two side walls. The top floor supports the antennas and the payload equipments and comprises:

The Skynet 4B military communications satellite being lifted from its integration trolley prior to an Ariane adaptor fit check



SHF package providing four channels at bandwidths from 60 to 135MHz using 40 Watts TWTAs. The SHF band will be used for communications to and from ground stations and surface vessels.

A UHF package of two transponders of 40 Watts, each serving one channel of 25kHz bandwidth. The UHF band will be used to communicate with submarines.

An EHF uplink channel for propagation experiments for future EHF systems.

Antennas:

SHF transmit and receive antennas, providing a variety of footprints from spot to Earth cover beams.

The UHF antenna is an Earth cover helix, deployed by telecommand once the satellite is on station.

This variety of spot and global beams enables Skynet 4B to serve an extensive inventory of Earth stations. The primary node of the Skynet network is the communications anchor station located at RAF Oakhanger in Hampshire. The Oakhanger facility is also used to control the satellites and is currently being up-dated by BAe with support from Marconi. Housed in existing premises the new Centre will be capable of controlling a number of communications satellites.

A major user of Skynet 4 will be the Royal Navy. Most of the fleet is fitted or is being fitted with enhanced SHF 'SCOT' warship terminals. Flight trials are already underway using airborne SHF terminals to demonstrate the feasibility of fitting larger RAF aircraft with terminals by the mid-1990s. These terminals have already undergone successful helicopter trials.

The Army is being equipped with mobile Land Rover terminals carrying a collapsible 1.7 metre antenna, whilst individual units have been supplied with even smaller manpack terminals capable of being carried by infantrymen in the field.

Skynet 4 has an ability to withstand different forms of electrical warfare. The spacecraft carries signal processing and anti-jamming equipment providing strong resistance to electronic counter measures attack. Built for an operational life of seven years, Skynet 4 was designed for robust system operation with good operational margins demanding the minimum of central control.

Launching Skynet 4B

Because of their military nature, Skynet 4 satellites were originally conceived to be launched by the Space Shuttle with support from British Payload Specialists. The first mission Payload Specialist, RAF Squadron Leader Nigel Wood would have been the first Britain in space but for the unfortunate accident which befell the Shuttle 'Challenger' in January 1986. As a result of the disaster, all four prospective British astronauts were grounded.

At the time of the accident, Skynet 4A was ready for launch aboard Shuttle. The subsequent delay in the Shuttle programme necessitated some redesign of the spacecraft for launch by an expendable launch vehicle (ELV). The necessary modification of the satellites, coupled with untimely failures in ELV programmes, resulted in Skynet 4B being the first of the three satellites ready for launch.

In September 1988 Skynet 4B was shipped to the Guiana Space Centre at Kourou, French Guiana. The satellite was prepared for launch in the S1A clean room where it underwent a series of integration systems tests. The solar arrays were then fitted, deployed for tests and then restowed. On October 31, the spacecraft was transferred to the S3A building where a BAe fuelling team filled and pressurised the satellite's tanks with hydrazine fuel and nitrogen. The ABM was then fitted together with the final blankets and the spacecraft was spin balanced.

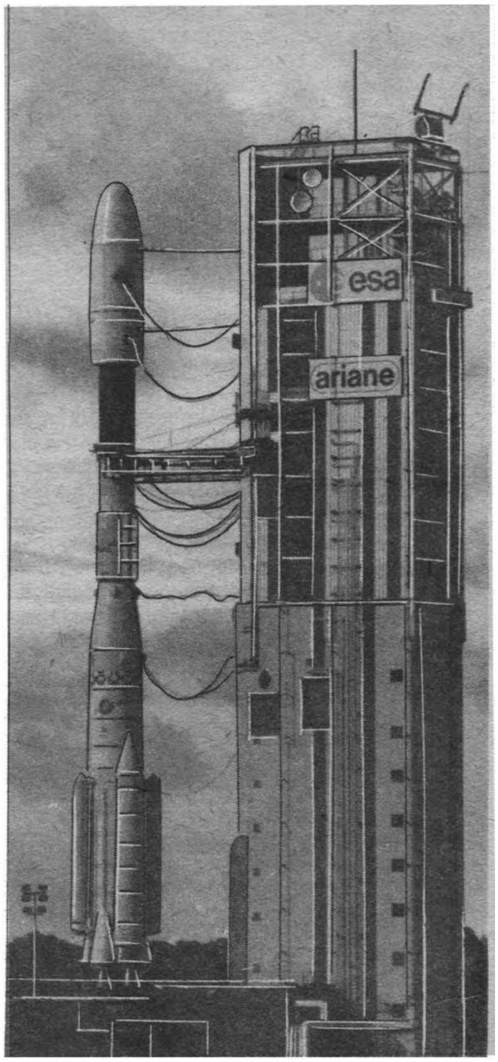
In late November, Skynet was mated with the Ariane adaptor and fitted to the top of the BAe manufactured SPELDA (Structure Porteuse Externe pour Lancement Double Ariane) — the dual payload structure which enables Ariane 4 to launch two or more satellites during the same mission. Astra 1A was already fitted inside SPELDA's cylindrical portion. After integration with the fairing, the entire structure was transported to the launch pad for mating with the launch vehicle.

On December 6 and 7, the Launch Rehearsal and Launch Readiness Review were held. The review gave clearance for launch and the countdown sequence commenced on 8th December.

On December 10 1988 (December 11 GMT) Ariane 4 successfully launched Skynet 4B into geostationary-transfer orbit. At 2029 GMT, on December 13 the satellite's ABM was successfully fired and drift orbit operations commenced. Sun acquisition was achieved at 0645 GMT, December 14th, and the solar arrays were deployed. On January 7, Skynet 4B arrived on station at 1° West.

On February 22, Lord Trefgarne, Minister of State for Defence Procurement, marked the introduction to service of the United Kingdom's Skynet 4B military communications satellite by making a call from Horse Guards Parade, London, to units in Germany. Using a man-portable transmitter, the Minister spoke via the satellite to Second Lieutenant Tony Clark of 21 Signals Regiment and Flight Lieutenant Richie Gardner of No 37 Squadron, RAF Regiment. Both officers were with units deployed in the field at RAF Wildenrath, near the West German/Dutch border.

In late 1989, Skynet 4A will be launched from Cape Canaveral by the first commercial launch of a Titan 3 vehicle; 4C is scheduled for launch by Ariane 4 in May 1990.



Ariane V27 stands on the launch pad with the Skynet 4B enclosed within its payload shroud

In January 1987, BAe received a contract to supply NATO with two NATO IV satellites based on the Skynet 4 design. The specification and flexibility of the Skynet system combined with the keen commercial price meant that this was the first time such a contract has been awarded to a non-US supplier.

The unsung success of Skynet 4B also reflects the little known yet important role of Britain as both a major user and supplier of communications satellites. It should be a matter of national pride that there are currently nine British built communications satellites in orbit operated by a number of national and international organisations. Two more will be launched this year with a further seven scheduled for launch in the following two years.

CORRESPONDENCE

Hermes and HOTOL

Sir, This letter is written in response to two letters published in the April 1989 issue of ***Spaceflight***. The first letter by Peter Hall refers to logistics support of the Freedom Space Station (FSS), whilst the second by M.Q. Hassan discusses using the An-225 as a launch platform for HOTOL and similar vehicles.

Space Station Resupply

Presently, the FSS is designed to be assembled and supported logistically using, at least initially, only the Space Shuttle at a maximum rate of 5 flights per year. Indeed, it is this low flight rate which limits the extent to which the FSS can be utilised and expanded. For this reason it is very clear, as Mr. Hall points out, that an additional manned servicing vehicle could be required. Unfortunately, however, the design of Hermes at the moment, as I understand it, precludes its use for regular servicing activities for the following reasons:

1. Flight Rate; The Hermes fleet is capable of flying a maximum of three or four times per year and it is planned that most or all of these flights will be devoted to servicing the Columbus Free-Flyer. At most, only one or two flights per year would be available for FSS servicing.
2. Payload; Hermes is being configured to carry a maximum up payload of three tonnes. However, the FSS requires between 90-100 tonnes/year purely for logistics, servicing and payload resupply. Thus at two flights/year, Hermes could only provide less than 10% of FSS requirements.
3. Crew Size; Hermes has a maximum crew size of three, two of whom are pilots needed to fly the vehicle during re-entry and landing. Thus, Hermes would only be able to rotate 1 mission specialist per flight. It is planned to rotate the 6 to 8 member FSS crew over 3 months.

Mr. Hall is correct in saying that it would be worthwhile spreading our limited resources. However, for the reasons outlined above, this may not be, in my opinion, the most economical area for NASA to invest its funds in Europe.

Piggy-Back into Orbit

During my involvement with the HOTOL project at British Aerospace (Space Systems) Ltd in Stevenage, I performed a study looking at a broad cross-section of 'Launch Assist Systems' (LAS) or trolley options for HOTOL. These options range from a fully integral undercarriage to air-launching, as described by Mr. Hassan, and indeed I referred directly to the An-225 since, as Mr. Hassan pointed out, it does have a payload capability near that of HOTOL's all up mass 275 tonnes.

HOTOL, I would like to emphasize, is being configured *solely* to minimise the operational or recurring cost of the system and, hence, the cost per kg to orbit. Now, because the LAS is an integral part of the system architecture, it follows that the ultimate choice for the way in which HOTOL is launched must also be the most cost effective. (It is critical to note that 'cost effective' also means, *by implication*, a highly reliable and safe operational system).

At this time, we believe that a ground based LAS is the best option *simply* because it would result in the lowest cost to orbit, as well as the lowest overall life-cycle cost, compared with any alternatives including air-launching. Therefore, we have optimised the vehicle to take-off from the ground.

Air-launching is an interesting possibility. However, at the present time it does not seem to be the most economical route which, ultimately, must be the prime requirement for future launch systems like HOTOL.

RUSSELL J. HANNIGAN
HOTOL System Engineer
BAe (Space Systems) Ltd

The logistics of Mir

Sir, After nearly three years, the Russians have now achieved a permanent bridgehead in space with a crew of two to three men on board the Mir-Kvant space station weighing 32 tons. To maintain this, at least 6 Progress cargoes of 2.3 tons are required per annum, conveying some 14 tons of consumables, experimental equipment and materials and rocket fuel.

In 1989-90 it is clear that the plan is

a) to increase Mir's mass by about 70-80 tons with four purpose built modules, and
b) to increase the resident crew to about 6.

The latter will be essential if the entire mission is not to be one long exercise in housekeeping and packing! It can be shown that, to maintain six men and 120 tons of hardware in Low Earth Orbit, some 50-60 tons of logistical supplies per annum will be required. This would need a Progress flight every three weeks or some 15-16 per year.

Using the new Energia/Buran system with its 30 tons to Low Earth Orbit capacity, only two flights per year would be needed. On each of these, six crew and two shuttle pilots and 30 tons of materials could be conveyed to Mir - a six months supply - at one go. Also 20 tons of finished products could be brought back.

This would be consistent with a flight rate of two per annum of the V.K.K. by 1990, once the test flight programme is complete, and would thus allow for extensive experience with the new system before Mir 2 is launched in 1994-95.

MICHAEL MARTIN-SMITH
Hull, UK

Artificial Gravity

Sir, I am surprised that there seems to be no future developments or experiments to test and use artificial gravity vehicles with the Mir or International Space Stations. When one thinks of the benefits of artificial gravity to the way astronauts work in space, why has there not been even a small plan to use artificial gravity vehicles with these space stations?

Why, when there have been countless designs of artificial gravity vehicles for over thirty years now, has no one taken the initiative to start a space station which uses artificial gravity? If man is to take a foothold in space he is going to have to overcome the problem of weightlessness.

ROBERT METCALFE
Hants, UK

An Occulting Artificial Satellite

Sir, Astronomers have been waiting patiently for many years for suitable occultation events of various solar system bodies. Yet if the object could be occulted in space by a suitably arranged system of black panels, I am sure that fast photometry at a ground based observatory could deduce equivalent information about the object. Some observatories have used this technique with the dark limb of a waning Moon as the occulting edge. I envisage a satellite in near polar orbit at about 2000 miles height consisting of black panels and a radio commanded laser for precision tracking. It would be in an orbit designed to be transitting the zenith each night over a major group of observatories. Though it would have to have panels up to 100 feet in extent to occult bodies up to an arc second, multiple panels providing a sequence of occultations could make this a very comprehensive technique that could be a very useful facility to the astronomical community.

P.W. SHIMMON
W.Sussex, UK

CORRESPONDENCE

Cosmos 1686 and Kvant

Sir, I have some theories regarding the picture of Cosmos 1686 in 'Correspondence' ***Spaceflight***, February 1989 (p.56). If the satellite's forward end is not the reentry capsule attached to the earlier Cosmos 1443, why must it be a telescope package, as Neville Kidger writes. The vehicle looks like the new module to be docked to Mir later this year, as illustrated on p.68 of the same edition. This module is said to have a large airlock to ease EVAs and was originally planned to fly before the joint Soviet/French mission for this purpose. Cosmonauts Kizim and Solovyov also carried out an EVA from Salyut 7 to erect a boom structure which was delivered by Cosmos 1686. Perhaps the module carried not only the boom but also an airlock.

At first sight Kvant seems to be an extra development and one not tested in advance. But it is more likely that Kvant conforms to the Soviet policy of reaching maximum reliability by using the same proven base units from many different spacecraft. In my opinion the tug module of Kvant has indeed flown at least once as a test vehicle. Could it have been Cosmos 1669, the small module that docked to Salyut 7 and was not from the Progress series of supply craft? Kvant itself is the backward section of a Salyut or Mir station, of which the propulsion unit surrounding the axial cross tunnel is replaced by the telescope unit. The gyros could have easily been tested as a system on another vehicle.

HEINZ MULLER
Bulach, Switzerland

Advertisements In Orbit

Sir, With reference to Mr. J.S.P. Wordie's letter (***Spaceflight***, December 1988, p.469) concerning the placing into orbit of a reflective ring and the opposition to it. I am concerned that such a ring may be used for other purposes.

With the cost of a satellite launch now within the yearly advertising budgets of many popular product manufacturers, how long will it be before the night sky is ablaze with company logos, giant silver hamburgers and soft drinks bottles.

P.S. NUTTON
Hants, UK

Tile Damage

Sir, In the STS-27 Mission Report (***Spaceflight***, February 1989, p.40) it was noted that the tile damage on the Orbiter Atlantis could have been caused by the impact of torn away insulation from the External Tank during launch.

One of the suspected reasons for this was said to be the age of the tank and the fact the tank was involved in cryogenic propellant testing at Vandenberg Air Force Base in conjunction with the Orbiter Enterprise.

While it is true that the tank was used in fit checks its is not true that the tank was used in cryogenic testing. The NASA official who suggested this scenario was wrong. Information from the manufacturers of the tank, Martin Marrietta, indicates conclusively there were no cryogenic tests on this or any other tank at Vandenberg. There has been no official comment on this from NASA.

LEE ROBERT CALDWELL
Toronto, Canada

Ed.- *We would like to thank Mr Joel Powell , who also raised this point..NASA has since revealed the Atlantis tile damage was caused by insulation breaking loose from the Solid Rocket Boosters.*

STS-29 **MISSION REPORT**

Discovery's Success

Discovery blasted off on her eighth mission on March 13 after a delay of almost a month. The third Tracking and Data Relay Satellite (TDRS-D) was successfully deployed, completing NASA's space communications network. The failure of the space station heat pipe experiment marred this otherwise successful mission. *Spaceflight* provides extensive coverage of the first shuttle flight of the year.

**Reports By
Roelof Schuilling
and
David Portree
at the Kennedy Space Center**

Launch Preparations

Preparations for STS-29 began immediately after Discovery was returned to the Kennedy Space Center (KSC) from Edwards Air Force Base on October 8, 1988. Discovery had to be launched by March 18, 1989 in order to roll Atlantis out to pad 39B in preparation for her important mission to launch the Magellan Venus probe. The second shuttle launch pad is at present undergoing modifications and refurbishment and is not expected to be available until the Autumn.

The day after Discovery's return to KSC, the vehicle was towed to Bay 1 of the Orbiter Processing Facility (OPF) for post-flight deconfiguration and inspections.

As planned, the three main engines were removed in October and taken to the main engine shop in the Vehicle Assembly Building (VAB) for the replacement of several components. During post-flight inspections, technicians discovered a small leak in the cooling system of the main combustion chamber of the No.1 main engine. The engine was returned to the manufacturers, Rocketdyne, for repairs and a new engine (2031) was delivered from NASA's Stennis Space Center in Mississippi.

Discovery's three main engines were installed before the end of last year (engine 2031 in the No.1 position, engine 2022 in the No.2 position and engine 2028 in the No.3 position).

The right hand Orbital Maneuvering System (OMS) pod was removed in late October and transferred to the Hypergolic Maintenance Facility where a small internal leak was repaired. The forward Reaction Control System assembly was also removed for cleaning and flushing. The orbiter's flash evaporator that malfunctioned during STS-26, causing uncomfortably high temperatures onboard Discovery, was replaced. Post-flight inspections had revealed the system was clogged with foreign material.

The Solid Rocket Booster (SRB) segments began arriving at KSC in September, and the first segment - the left aft booster - was stacked on Mobile Launcher Platform 2 on October 21. Booster stacking operations were completed in early December and the External Tank was mated to the boosters on January 16.

The TDRS-D arrived at the Vertical Processing Facility (VPF) on November 30. Work to prepare the IUS booster suffered a serious setback when a technician slipped and fell against the Inertial Upper Stage (IUS) first stage nozzle damaging it beyond repair and rendering the entire first stage useless. A replacement first stage was transported to the Cape and installed in time to meet the launch schedule. The TDRS and IUS were joined together on December 29 and the connections between the two tested during the first week of January.

Launch preparations were running smoothly, and it appeared the schedule could easily be met. But the flight of STS-27 revealed a potentially dangerous situation. Postflight inspection and analysis of the No.3 main engine high pressure oxidizer turbopump revealed cracks in the inner race of one of four bearings in the pump. The cracks were believed to be due to stress corrosion caused by moisture entering the pumps during manufacture.

A decision was made to replace the oxidizer turbopumps with ones manufactured under a different process that eliminated the moisture problem. Shuttle managers decided to continue with preparations for STS-29 as the new turbopumps could be installed once Discovery was on the launch pad.

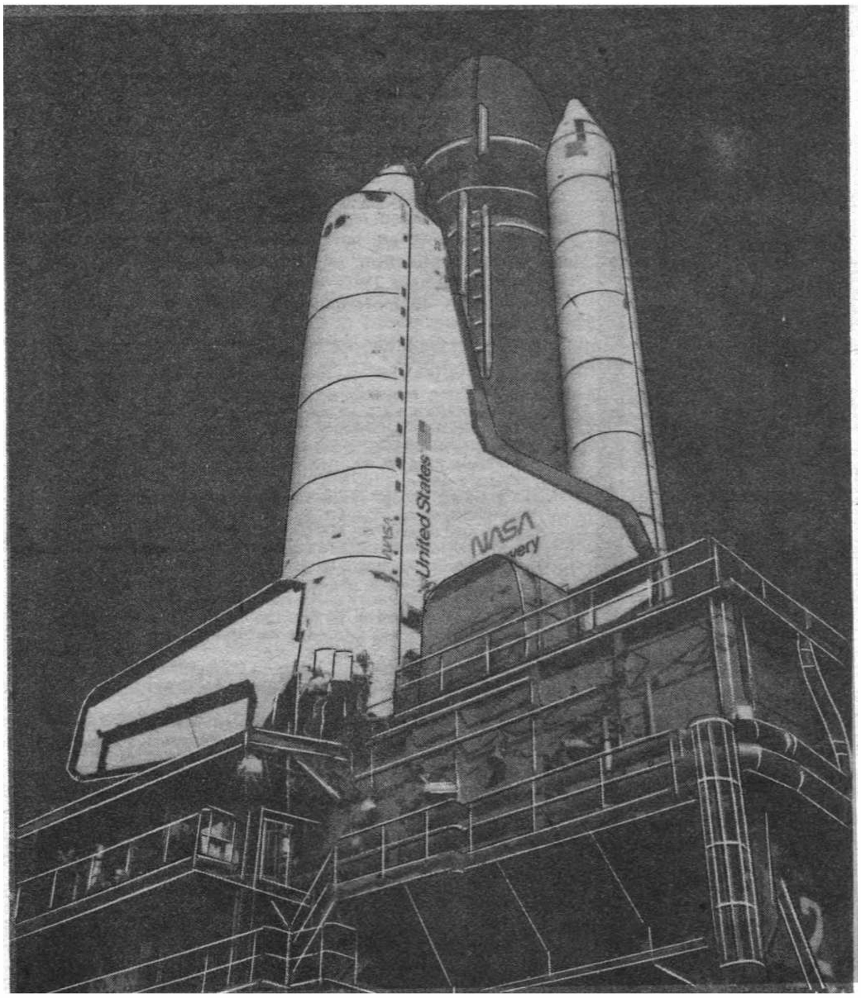
In addition to the concerns about the oxidizer turbopumps, considerable damage to Atlantis' heat protection tiles during STS-27 prompted an investigation to determine the cause. It was discovered insulation from the top of the right hand SRB had broken away and struck the orbiter during the launch. Efforts were made to prevent the same incident occurring on STS-29.

Discovery was towed the 400 yards from the OPF to the VAB on January 23 for mating to the External Tank and SRBs. The orbiter was hoisted into a vertical position by the 250 ton VAB crane and attached to the External Tank on January 25.

On February 3, the assembled shuttle vehicle was rolled out of the VAB atop its mobile launch platform for the 4.2 mile trip to launch pad 39B. TDRS-D and its IUS upper stage had been moved to the changeout room at the pad on January 17. The satellite was fuelled with hydrazine before being installed in Discovery's payload bay on February 6.

The Countdown Demonstration Test began at the T-24 hour point on February 6 and was completed at T-5 seconds with a simulated main engine shutdown. During the final stages of the

Discovery after departing the Vehicle Assembly Building during roll out to Pad 39B at the Kennedy Space Center on February 3. *NASA*

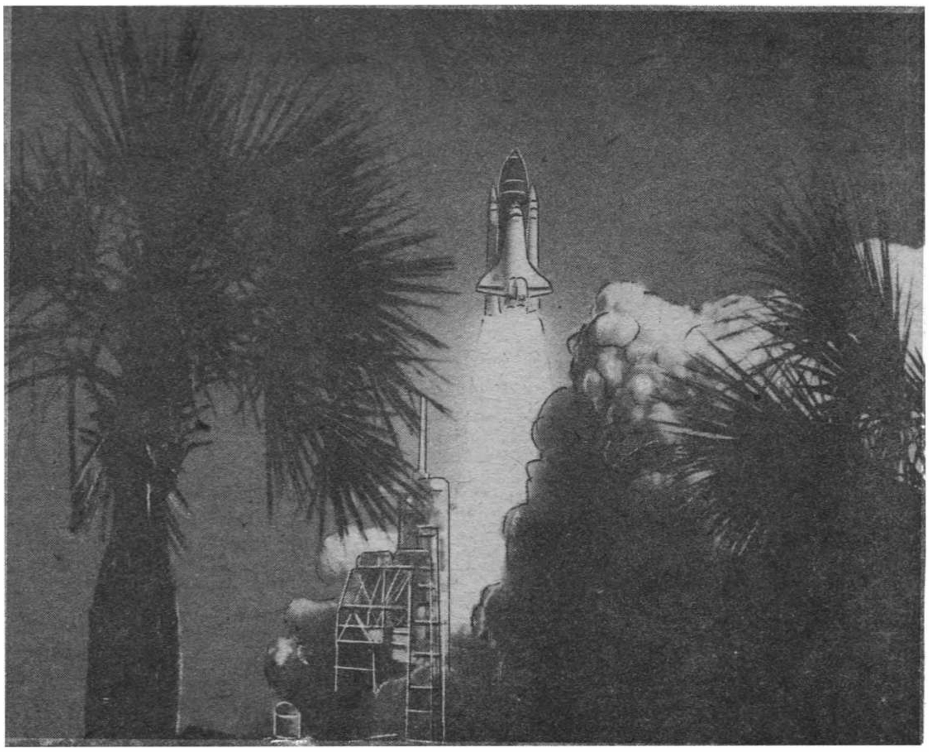


test the STS-29 crew boarded Discovery as a rehearsal for launch day.

While the mock countdown went ahead work began to remove the questionable oxidizer turbopumps from Discovery. Replacement units began arriving at KSC on February 15 from the Stennis Space Center, where they had undergone rigorous testing. The pumps were delivered and installed earlier than expected and the work was completed on February 22.

Shuttle managers met on March 2 and 3 for the Flight Readiness Review and set Discovery's launch for March 10. However on March 5, Discovery's Master Events Controller failed. The controller is responsible for the operating the pyrotechnic devices that separate the SRBs and External Tank. Columbia's controller was removed and installed in Discovery's aft compartment. To avoid the risk of accidental detonation, the pyrotechnic charges were removed prior to the installation and testing of the new controller. By the time the charges had been reconnected and the new Master Events Controller tested, the launch date slipped two days to 13:07 GMT on March 13.

The countdown began shortly after midnight on Friday March 10. The STS-29 crew had arrived at KSC earlier that afternoon. The countdown proceeded as planned until the first built-in hold. High winds caused the final closeout operations on the shuttle to be delayed. To compensate, the first built-in hold was extended and the second compressed. By the evening of the next day the count was back on schedule, there were no further delays until the morning of the launch.



Discovery is framed by palm trees as she blasts off at 14:57 GMT on March 13. *NASA*

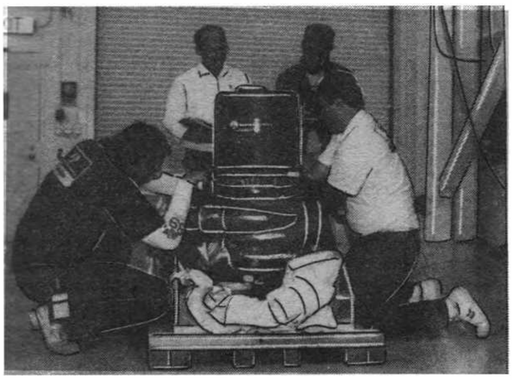
Ascent

On the morning of March 13, the rising Sun conspired with the moisture-laden Florida air producing dense ground fog that obscured the launch pad and prevented the range safety crew from monitoring Discovery's ascent. The upper third of the 200 metre tall VAB was lost in cloud. In addition upper wind conditions required additional analysis to ensure that structural loads during launch would not be excessive. A decision was made to continue with the countdown until the T-9 minutes mark - a built-in hold is scheduled at this point, usually lasting ten minutes. The launch team decided that this would be the optimum point to wait for the fog to clear and the analysis of the upper wind conditions to be completed. At 13:00 GMT US Air Force sources gave Discovery only a 40% chance of launching that day.

The countdown commentary was provided by NASA Public Affairs Officer Lisa Malone - the first woman to do so in the history of the US manned space programme. At 14:48 GMT, Lisa was able to inform the press and public the countdown had resumed. The fog had dissipated, the upper wind analysis had been completed and the rising cross-winds which might have hampered a Return to Launch Site abort were judged to be within constraints.

The last nine minutes proceeded under the control of the Ground Launch Sequencer. At T-31 seconds the ground computers gave a 'go' for 'Auto Sequence Start' - the countdown was now under the control of the orbiter's onboard computers. At T-6.6 seconds the main engines were fired, by T-0 they had reached full power and the SRBs were ignited. The launch pad's eight holddown posts released their grip on the vehicle and the 28th shuttle mission began. The sound of the launch reached the press grandstand 15 seconds later and shook it, drowning out the cheers which had begun at the moment of SRB ignition.

Technicians inspect the first of the replacement oxidizer turbopumps to arrive at KSC. *NASA*



As the shuttle cleared the launch tower, control of the mission shifted to Houston. Nine seconds after blast-off, the main engines and SRBs steered the orbiter into a 120 degree roll, putting the shuttle into a 'heads down attitude' and on the correct trajectory for a 28.5 degree inclination orbit.

As Discovery climbed towards orbit, long-range tracking cameras were trained on the vehicle to check the SRB insulation remained intact.

The throttle down of the main engines to 65% was achieved at T+28 seconds, returning to 104% 39 seconds later. At T+2 minutes 6 seconds, the two SRBs cleanly separated from the External Tank, leaving the three main engines to lift the shuttle into orbit.

The main engine finished their work at T+8 minutes 32 seconds. Twelve seconds later the External Tank separated from Discovery. Shortly after separation, Discovery's crew photographed the departing tank through the flight deck upper windows to record the extent of thermal damage to the tank's skin (see overleaf for photograph).

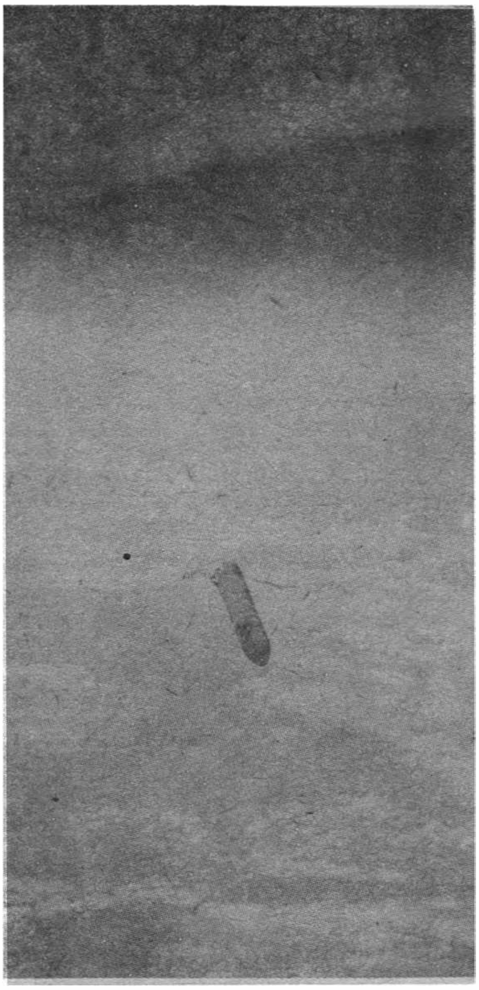
A firing of the OMS engines at T+40 minutes circularised Discovery's initial orbit of 156 x 35 nautical miles (nm) to 160 x 160 nm.

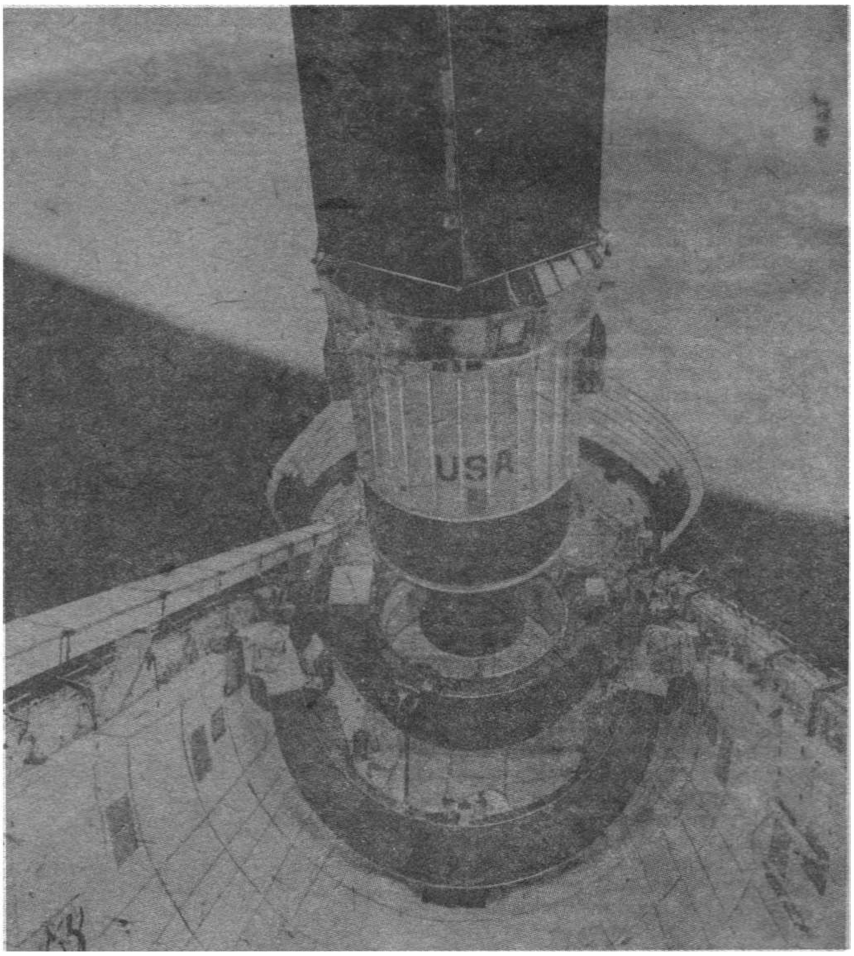
Day One: March 13, 1989

As Discovery's crew awaited a 'go' for on-orbit operations Discovery completed its first orbit and passed over the Kennedy Space Center. Commander Coats chose this "fitting time" to pay tribute to "all the main engine people that did such a good job getting our engines in shape." Coats was referring to the quick replacement of the main engine turbopumps in time to beat the March 18 deadline for launch.

The first problem was detected early in the flight. During a post-ascent checkout of Discovery's onboard systems there was an unusual pressure fluctuation in cryogenic hydrogen tank No.3 which threatened to shorten the mission by a day. The cryogenic hydrogen and oxygen tanks feed the orbiter's fuel cells, which provide power for the shuttle. The suspect tank was shutdown and the crew was asked to power down some non-essential systems, including the cabin lights.

The 18 metre long payload bay doors were opened 1 hour and 20 minutes into the flight exposing Discovery's precious cargo. Extensive checkouts of the TDRS-D satellite were made. At approximately T+4 hours and 30 minutes the satellite was tilted to 29 degrees on its Airborne Support Equipment (ASE). Checks on the satellite continued and almost six hours into the mission the crew were given the 'go' for deployment. The astronauts fired charges to sever umbilical connections between the shuttle and the TDRS/IUS, then tilted the ASE structure to its deployment angle of 52 degrees.




USA

At T+6 hours and 13 minutes pyrotechnic charges separated TDRS-D and its IUS booster from the ASE. This action released compressed springs which provided the force to jettison the TDRS/IUS at approximately 0.1 metres per second.

Commander Coats fired Discovery's Reaction Control System (RCS) thrusters moving the shuttle away from the departing satellite. An OMS firing, 15 minutes after deployment, further separated the two spacecraft. After manoeuvring to observe the TDRS/IUS combination, Coats turned the orbiter so its belly faced the satellite, thus protecting the shuttle's windows from the exhaust of the IUS booster.

Exactly an hour after deployment the IUS first stage ignited, firing for 146 seconds. Approximately six hours 12 minutes after deployment the IUS second stage fired for 108 seconds.

With the main objective of the mission successfully completed, the STS-29 crew conducted further IMAX photography and activated the Protein Crystal Growth Experiment. After a busy day in orbit the crew went to bed about ten hours after blast-off.

Day Two: March 14, 1989

The crew of Discovery were woken by Mission Control at 03:37 Houston time by a tape recording of musician James Brown singing "I feel good". Brown is currently in jail in South Carolina and Michael Coats accused Mission Control of getting Brown out on parole so he could wake the shuttle crew.

A full day of activity ensued. The SHARE heat pipe experiment was powered up, however, the experiment had to be shutdown. Readings indicated unexpected fluid behaviour - it was believed that heaters were evaporating ammonia faster than it could recirculate.

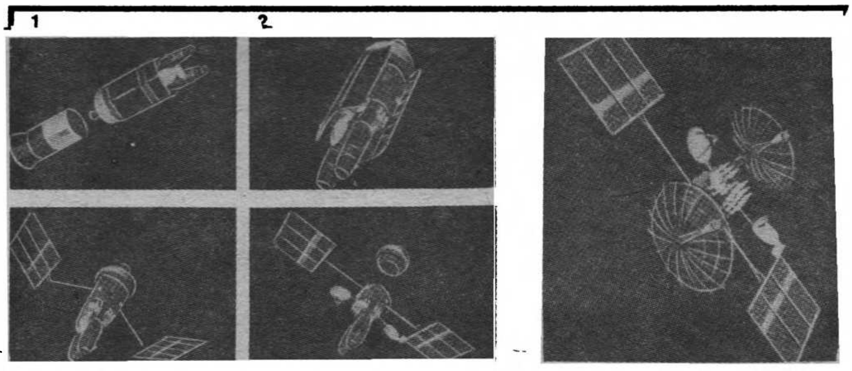
Extensive IMAX photography was undertaken. However during operation the belt on the camera's drive mechanism came off track causing the loss of about 200 feet of film. The Discovery crew replaced the belt and normal camera operations continued.

Checks of the Chromex experiment revealed a slight over-heating problem. Mission Control began an analysis of the problem.

Day Three: March 15, 1989

The crew of Discovery was woken early on day three by Mission Control playing a brass band's rendition of the US Marine Corps Hymn. Mission Specialists Springer, Buchli and the CAPCOM - who selected the music - Ken Cameron were all members of the Marine Corp. Commander Coats, a Navy man, joked with Mission Control that he had "Two Marines

(Top left) Astronaut James Bagian took this photograph of the External Tank (ET) about eight minutes after it had separated from Discovery. Note the burn scar on the left of the ET, above the SRB forward attach point, caused by the SRB separation motors.
(Top right) The TDRS-D satellite slips from its berth in the payload bay. Note the SHARE radiator located along the edge of the left hand side of the payload bay.
(Bottom) Commander Coats is photographed updating the STS-29 flight plan. A drink dispenser floats in front of him.
NASA



1. The first stage of the IUS separates from the TDRS.
2. After the first stage separation, the satellite's outboard solar panels unlatch.
3. A flat array is created and inboard solar panels are unlatched enabling the array booms to extend.
4. When the solar panels are fully extended, the space/ground link and C-band antenna are sequentially deployed and the second stage of the IUS separates from TDRS.
5. The large umbrella-like single access antennas open and the TDRS is fully deployed.

TDRS-D *Completes NASA's Tracking Network*

TDRS-D is the third TDRS satellite to be placed in orbit. TDRS-1, launched on STS-6 in April 1983, is located in the TDRS-East position at 41 degrees West, East of Brazil over the Atlantic Ocean. TDRS-3 was launched by Discovery during STS-26 last September. The Satellite is located in the TDRS-West position at 171 degrees West, just south of Hawaii.

TDRS-D, renamed TDRS-4 after reaching orbit, will replace the aging TDRS-1 at 41 degrees West. TDRS-1 will be moved to 79 degrees West where it will serve as an on-orbit spare incase one of the operational satellites malfunctions.

(For further details of the TDRS system see *Spaceflight*, November 1988, p.443.)

SHARE
Experiment Fails

The SHARE (Space Station Heat Pipe Advanced Radiator Element) experiment was to test a new method for a potential cooling system of space station Freedom. Despite repeated attempts by the crew, the experiment refused to operate. Air bubbles trapped in the radiator were thought to be responsible. The experiment was mounted on the starboard sill of the Orbiter's payload bay with a small instrumentation package mounted in the forward payload bay.

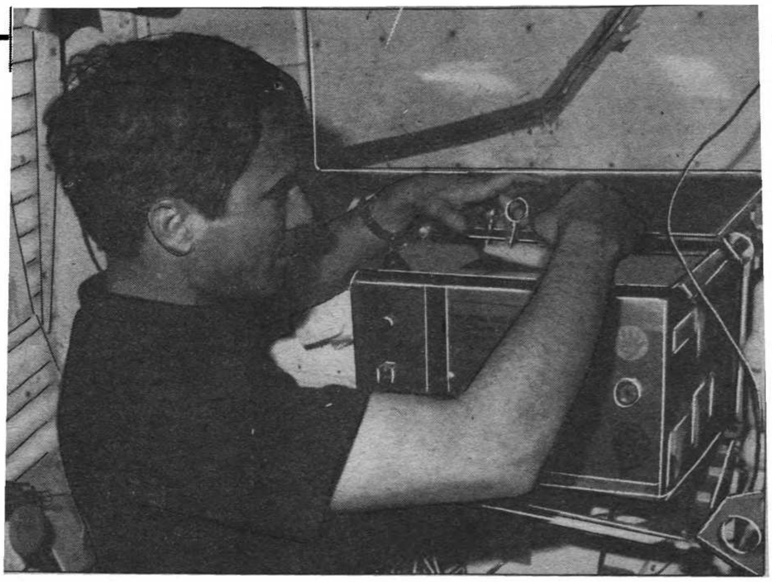
The heat pipe method uses no moving parts and works through the convection current of ammonia. Three electric heaters will warm one end of the 51-foot long SHARE. The heaters turn liquid ammonia into vapour which transports the heat through the length of the pipe, where a foot-wide aluminum fin radiates it into space. The fin is cooled by the space environment, and the ammonia is, in turn, condensed and recirculated.

Two small pipes run through the centre of the radiator down its length, branching out like the tines of a fork at the end that receives heat, called the evaporator. The top pipe holds the vaporised ammonia; the bottom holds liquid ammonia. In the evaporator portion, a fine wire mesh wick, which works along the same principle as the wick of an oil lamp, pulls the liquid ammonia from one pipe to the other, where it vaporises. Small grooves allow the condensed ammonia to drop back to the bottom pipe.

The radiator for SHARE weighs about 135 pounds, but with its support pedestals, support beam, heaters and instrumentation package, the total experiment weighs about 650 pounds.

Each of the experiment's two 500-watt heaters and single 1,000-watt heater is controlled individually and can be switched on in turn, applying heat that increases steadily in 500-watt increments up to a maximum of 2,000 watts.

The experiment was to have been activated for two complete orbits in two different attitudes, the first with the payload bay toward Earth and the second with the orbiter's tail toward the Sun. The heaters can go through a complete 500 watt to 2,000 watt cycle. This simulates the heat that needs to be dissipated from the space station and the two attitudes will provide data on the heat pipe's operation in different thermal environments.



John Blaha, checks the chicken embryo experiment incubator on the middeck of Discovery. *NASA*

Student Experiments

Chicken Embryo Development in Space

This experiment, proposed by John Vellinger, was one of two experiments flown under the Shuttle Student Involvement Programme (SSIP). The experiment was designed to determine the effects of space flight on the development of fertilised chicken embryos. Discovery carried 32 chicken eggs - 16 fertilised two days prior to launch and the other 16 fertilised nine days prior to launch. An identical group of 32 eggs remained on Earth as a control group.

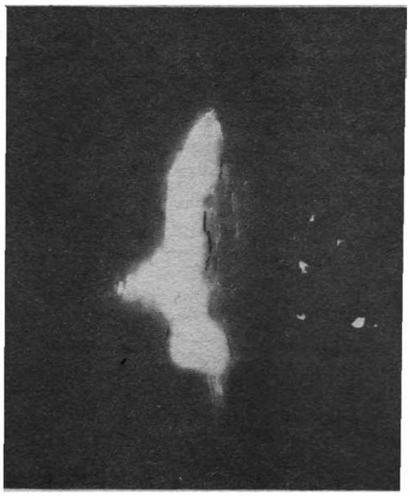
On return to Earth, half of both group of eggs were opened and examined to identify any differences in cartilage, bone and digit structures, muscle system, nervous system, facial structure and internal organs. The second half (16 space flight and 16 control) were hatched 21 days after fertilisation. All the embryos fertilised two days before being carried into orbit were found to be dead, experimenters are now trying to determine the cause.

The experiment first flew on STS 51-L and was lost when Challenger was destroyed. John Vellinger had been waiting more than nine years for his project to fly in space.

The Effects of Weightlessness on the Healing Bone

The second SSIP experiment, proposed by Andrew Fras, was to establish whether weightlessness inhibits bone healing.

Observations from previous space flights have shown that minerals, calcium in particular, are lost from the body, resulting in a condition similar to osteoporosis. Calcium is the main mineral needed in bone formation. Four Long Evans rats had a minute piece of bone removed from a non-weight bearing bone prior to launch. A similar group of rats remained on Earth as a control group. After Discovery's return to Earth, effects of weightlessness on the origin, development and differentiation of the osteoblasts (bone cells) and their production of Callus were studied.



AMOS

The AMOS (Air Force Maui Optical Site Calibration Test) experiment allowed ground-based electro-optical sensors located on Mt. Haleakala, Maui, Hawaii, to collect imagery and signature data of the orbiter as it passed overhead.

The observations made of Discovery, while performing Reaction Control System thruster firings, water dumps or payload bay light activation, will be used to support the calibration of the AMOS sensors and the validation of spacecraft contamination models.

(Left) Discovery on its final day in orbit is pictured by a US Air Force tracking system. *NASA*

standing at attention" and he didn't know what to do with them.

Flight controllers studying the hydrogen tank problem discovered similar readings had been received from Discovery during STS-26, and traced the problem to erratic heater operations. Two heaters are used to adjust the pressure of in each tank and force the liquid hydrogen into a pipe that carries it to the fuel cells. The crew were told to activate heater B in tank No.3, and the system operated normally.

Discovery's crew again attempted to operate the SHARE experiment. But the operation was terminated 28 minutes into the run when the experiment seemed to be drying out. Indications of what appeared to be bubble formation in the ammonia were being seen. Operations of the heat pipe in a one-gravity environment had not shown that behaviour.

The Chromex experiment appeared to be operating normally. The crew had applied temperature-indicating decals to the outside of the experiment in order to monitor its temperature which had been causing concern earlier in the flight..

Extensive IMAX photography of the Earth was conducted with particular emphasis on environmentally threatened areas. Mission Specialist Dr. James Bagian took a series of blood pressure and heart rate readings of crewmen.

Flight controllers determined that the landing at Edwards Air Force Base would occur one revolution earlier than originally planned due to lighting conditions. This would also give Discovery an additional back-up landing opportunity.

Day Four: March 16, 1989

A few minutes before the astronauts were to be awakened on day four, Discovery's crew turned the tables on Mission Control and sent Houston a wake-up message. It consisted of the theme music from the popular television and film series Star Trek and was followed by a taped message by actor William Shatner, who plays Star Trek's Captain Kirk. He told Mission Control the crew were prepared to "Boldly go where no astronaut has gone before".

Later that morning, President George Bush made his first presidential phone call to a spacecraft, congratulating the crew and all of NASA for the success of the mission. The President told the crew. "The space programme, especially space station Freedom, is an investment in our future. We're living in tough budgetary times, but I am determined to go forward with a strong, active space programme."

The SHARE heat pipe experiment continued to malfunction. The crew fired Discovery's thrusters in an attempt to shake loose a suspected air bubble that was thought to be blocking the pipe.

The IMAX camera photography continued, and the crew provided television coverage of the chicken eggs while discussing the experiment with developer John Vellinger.

Television coverage also caught a spectacular water dump from Discovery's fuel cells. Excess water was pumped overboard for ten minutes as the shuttle passed over the Pacific Ocean. The television camera caught the discharge as it trailed away from the orbiter. At the same time, the AMOS sensors in Hawaii monitored the discharge.

During a test of the Text and Graphics System (TAGS) that will be used to uplink photographs and graphics on future missions, a copy of the Johnson Space Center's inhouse news-

paper, "Space News Roundup", was sent to Discovery. CAPCOM Pierre Thuot said the transmission marked the first newspaper delivery to a US spacecraft.

Day Five: March 17, 1989

Preparations for reentry and landing dominated the activity on day five. Checking out of the Shuttle's flight control surfaces and RCS were underway in the morning. Equipment stowage and the shutdown of experiments were carried out later. In addition, the crew took part in a news conference with television reporters.

Despite continued efforts to free the suspected bubbles in the SHARE radiator, including rotating Discovery by firing thrusters, the experiment continued to malfunction.

Day Six: March 18, 1989

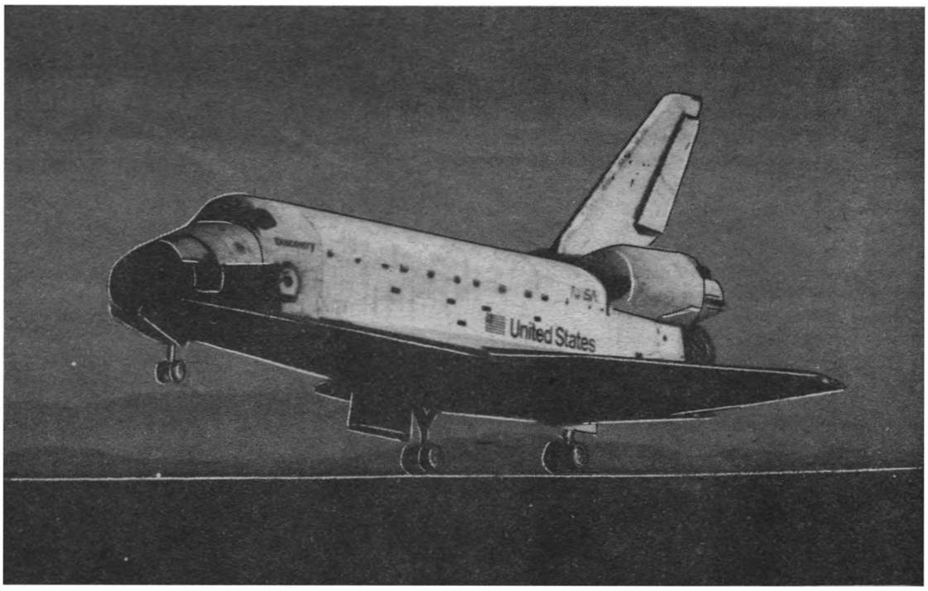
On the final day of the mission, crew member's children woke them with calls of 'wake up' and 'get up'. The crew made their final preparations for landing and closed the payload bay doors. At 07:35 Houston time Discovery's OMS engines fired for two minutes 37 seconds to begin the descent.

Winds proved too calm for a planned crosswind landing test. Instead, NASA officials opted for an alternative test - a braking exercise on the concrete Runway 22 at Edwards.

At 08:35:49 Houston time, Discovery's main landing gear touched down at Edwards Air Force Base. The nose gear contacted the runway 11 seconds later and wheel stop occurred at 08:36:40. Over 450,000 people had come out to watch the landing. The crowd was second only to that at the July 4, 1982 landing of Columbia.

After leaving the orbiter, Commander Coats told the crowd. "We have just concluded a five-day flight with essentially zero problems, and that's really a credit to the people who work so hard to build and get these shuttles ready to fly."

NASA had no time to celebrate the first shuttle flight of 1989. With six more missions planned before the end of the year, work began the moment Discovery blasted off to prepare the pad for Atlantis and its payload - the Magellan probe. Within days both were in position on pad 39B, poised for an April 28 launch.



Discovery's main gear touches down on the concrete Runway 22 at Edwards Air Force Base, California after after a successful five day flight. *NASA*

STS-29 AT A GLANCE

ORBITER: Discovery (OV-103)
LAUNCHED: 14:57 GMT, March 13, 1989
LAUNCH SITE: Pad 39B, Kennedy Space Center, USA
LANDED: 14:36 GMT, March 18, 1989
LANDING SITE: Runway 22, Edwards Air Force Base, USA
LIFT-OFF WEIGHT: 4,525,139 pounds
LANDING WEIGHT: 194,616 pounds
APOGEE: 160 nautical miles
PERIGEE: 160 nautical miles
INCLINATION: 28.45 degrees
DURATION: 4 days 23 hours 39 minutes 40 seconds
ORBITS: 79.5

COMMANDER: Michael L. Coats
PILOT: John E. Blaha
MISSION SPECIALIST 1: James F. Buchli
MISSION SPECIALIST 2: Robert C. Springer
MISSION SPECIALIST 3: James P. Bagian

PRIMARY PAYLOAD: TDRS-D/IUS-9
SECONDARY PAYLOADS:
- Space Station Heat Pipe Advanced Radiator (SHARE)
- Orbiter Experiments, Autonomous Supporting instrumentation System (OASIS)
- Protein Crystal Growth (PCG)
- Chromosome and Plant Cell Divisionin Space (CHROMEX)
- IMAX camera
- Air Force Maui Optical Site Calibration Test (AMOS)
- Chicken Embryo Development in Space (SSIP 83-9)
- Effects of Weightlessness in Healing of Bones (SSIP 82-08)

THE CREW

COMMANDER
Michael L. Coats (Captain USN)

Born on January 16, 1946, in Sacramento, California, Coats considers Riverside, California, his hometown. He became an astronaut in 1978.

Coats was a member of the STS-4 support crew, and was Capsule Communicator (CAPCOM) for STS-4 and STS-5. He was the pilot of the 14th shuttle mission (STS 41-D) launched August 30, 1984, Discovery's maiden flight. In February 1985 he was assigned spacecraft commander of STS 61-H. Following the Challenger accident he continued training with his crew in preparation for the resumption of shuttle flights.

During launch and landing, Coats occupied the left forward seat on the flight deck.

PILOT
John E. Blaha (Colonel, USAF)

Born on August 26, 1942, in San Antonio, Texas, Blaha, made his first space flight on STS-29. He joined NASA as an astronaut in 1980.

From September 1981 to March 1983 Blaha was a member of the Space Shuttle ascent/entry development and verification teams. During this period he managed and led the design, development and integration of the Orbiter Head-up Display System. From April 1983 to October 1984 he was an ascent, orbit, planning and entry CAPCOM in Mission Control for 7 shuttle flights. He was assigned as lead CAPCOM for Missions STS 41-D and STS 41-G. In January 1985 he began to train as pilot with the STS 61-H crew at the time scheduled to fly in December 1985. Due to payload rescheduling, the 61-H crew was reassigned to launch in June 1986. Following the Challenger accident, Blaha was assigned to as the Astronaut Office representative of the Space Shuttle ascent/abort reassessment team and the Orbital Maneuvering System/Reaction Control System reassessment group. In September 1987, Blaha was assigned to the Orbiter Project Office where he was the astronaut representative at Orbiter Management Reviews and Orbiter Configuration Boards.

Blaha occupied the right forward seat on the flight deck.

MISSION SPECIALIST 1
James F. Buchli (Colonel, USAF)

Born on June 26, 1945, in New Rockford, North Dakota, he considers Frago, North Dakota, his hometown. He is a member of the astronaut intake of 1978.

Buchli was a mission specialist on STS 51-C launched on January 24, 1985. The first military shuttle mission included the deployment of a modified Inertial Upper Stage from Discovery.

He next flew October 30, 1985, as a mission specialist on STS 61-A, the West German Spacelab D1 mission.

Buchli was a member of the support crew for STS-1 and STS-2, and on-orbit CAPCOM for STS-2.

Buchli occupied the seat immediately behind and between the Commander and Pilot on the flight deck, he assisted in monitoring the orbiter's systems.

Continued...

MISSION SPECIALIST 2
Robert C. Springer (Colonel, USMC)

Born on May 21, 1942, in St. Louis, Missouri, Springer considers Ashland, Ohio, his hometown. He became an astronaut in 1980 and was making his first space flight.

Springer's NASA assignments have included support crew for STS-3, concept studies for the Space Operations Center, and coordinating the various aspects of final development of the Remote Manipulator System for operational use. In 1984 and 1985 he worked in the Mission Control Center as a CAPCOM for seven flights. Springer was responsible for Astronaut Office coordination of design requirements reviews and design certification reviews, part of the total recertification and reverification of the Space Shuttle, prior to STS-26's return to flight.

During launch Springer occupied the right aft seat of the orbiter flight deck. For the landing he exchanged seats with Bagian and rode in the orbiter middeck.

MISSION SPECIALIST 3
James P. Bagian (M.D.)

Born on February 22, 1952, in Philadelphia, Pennsylvania, Bagian was making his first space flight. He became an astronaut in 1980.

Bagian participated in the planning and provision of emergency medical and rescue support for the first six shuttle flights and has participated in the verification of Space Shuttle flight software. In 1986, Bagian became an investigator for the 51-L accident board and has been responsible for the development of the pressure suit and other crew survival equipment. Bagian has also been a member of the NASA Headquarters Research Animal Holding Facility Review Board.

During ascent Bagian sat in the middeck and for landing occupied the right aft position in the flight deck.

The crew of STS-29 along side their spacecraft after a successful landing at Edwards AirForce Base (Left to right) John Blaha, James Bagian, Michael Coats, James Buchli and Robert Springer *NASA*

June 1989 US$3.25 £1.25

Spaceflight

The International Magazine of Space and Astronautics

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DISTRIBUTION DETAILS

Spaceflight may be received worldwide by mail through membership of the British Interplanetary Society. Details from the above address. Library subscription details are also available on request.

* * *

Spaceflight is distributed in the UK and overseas through newsagents by AGB Impress, Cloister Court, 22-26 Farringdon Lane, London, EC1R 3AU. Tel: 01-253 3135.

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Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

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Back issues of *Spaceflight* are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published monthly by the British Interplanetary Society Ltd., 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L., Ltd., Aylesbury, Buckinghamshire, England.

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Spaceflight

The International Magazine of Space and Astronautics

Vol.31 No.6 **June 1989**

Front Cover: Buran orbits high above the Earth in a painting by BIS member *Peter Eickmeyer.* Soviet officials have revealed Buran will fly again next year (see p.186).

Atlantis Gets Magellan Underway

The first interplanetary probe to be deployed by the Space Shuttle has begun its long journey to Venus. Atlantis blasted off on her second attempt and completed a flight which NASA officials described as '100%'. The Magellan probe was successfully deployed just over six hours into the flight. Onboard Atlantis for her four day mission were: Commander David Walker, Pilot Ronald Grabe and Mission Specialists Norman Thagard, Mary Cleave and Norman Thagard.

The First Launch Attempt

At the Flight Readiness Review, held on April 13/14, the launch of STS-30 was set for April 28 at 19:24 BST.

Ever cautious NASA officials included more than 38 hours of built-in holds in the STS-30 countdown to allow time to solve any last minute problems. The careful planning almost proved unnecessary, as what followed was described as the smoothest countdown in Shuttle history - until the final hour.

As the Sun rose on the morning of April 28, there was no threat from the weather, as there had been to the previous three missions. An Air Force Meteorological Officer said it was "perfect weather to go flying". The crew left their quarters about three hours before the planned blast-off and entered the orbiter 25 minutes later.

The countdown continued smoothly reaching the T-9 minute point without incident. During the 40 minute built-in hold planned for this point, the Mission Management Team, led by ex-astronaut Robert Crippen, polled the launch team seeking their approval for blast-off. But the Range Safety Officer refused to give his consent because of a malfunctioning range safety computer.

The fault had not been repaired at the point the countdown was scheduled to resume. The delay was now eating up the launch window. STS-30 had one of the shortest launch windows in the Shuttle's history - just 23 minutes. The window was dictated by the lighting conditions at the Trans-Atlantic Landing (TAL) site in Ben Guerir, Morocco. Launch rules allow a landing 15 minutes after sunset. Previously the rules prohibited a landing ten minutes after sunset, but this was extended shortly before STS-30. NASA Public Affairs Officer Hugh Harris, who was providing the countdown commentary, began to countdown the minutes left in the launch window. Launch Director, Robert Sieck, proposed the countdown should continue until the T-5 minute point, where it would hold until the problem was resolved or the launch window expired. But before this plan could be carried out a cheer went up in the Launch Control Center. The Range Safety Officer had given his 'go' for launch - the computer had been repaired. Bob Sieck radioed Commander Dave Walker in Atlantis' cockpit with the good news.

The countdown had been delayed five minutes and was to resume at 19:20 BST. Work began to synchronise the various countdown clocks on the ground and onboard the Shuttle to the new launch time of 19:29 BST. The countdown restarted and continued in the smooth fashion that had become accustomed for this mission.

The orbiter access arm was retracted, pilot Ron Grabe started the orbiter's Auxiliary Power Units (APUs), the orbiter switched to its internal power and the External Tank was pressurised. The countdown had entered its final minute, when Hugh Harris announced the clock would hold at T-31 seconds. A fault had been detected in a main engine recirculation pump and the countdown was ordered to stop. Lift-off could not take place that day - only 18 minutes remained in the launch window and the countdown would have to be recycled to the T-20 minute point.

Bob Sieck ordered the vehicle to be 'safed'. The orbiter access arm was moved back into position and the crew began to shutdown onboard systems, including the APUs and fuel cells. The crew left the orbiter, while engineers checked out the problem with the recirculation pump.

Pump Stops Launch

Prior to ignition the pump injects liquid hydrogen into the engine to cool its components before the bulk of the supercold fuel enters the engine. It was hoped the failure was with the pump's electrical supply from the launch pad so repairs could be made to allow a launch the next day. But engineers discovered the problem was a mechanical failure within the pump. A delay of three days seemed likely - then a second problem emerged. Replays of video from the launch pad cameras showed a vapour cloud in the region of the umbilicals that connect the orbiter to the external tank. Engineers immediately suspected a liquid hydrogen leak. Closer examination confirmed this. There was a small hole in the casing around a hydrogen pipe. The launch was at first postponed for at least three days. But after assessing the situation NASA delayed the launch a further three days.

The faulty pump and leaking pipe were replaced ahead of schedule and NASA officials reset the launch date for May 4 at 18:48 BST. However weather conditions were expected to be poor on the new launch date. Atlantis was only given a 60% chance of blasting off that day.

Launch Day

Sure enough the weather on launch day was the main problem. Showers drifted across the space centre and at the Shuttle Landing Facility (SLF) runway, located a short distance from the launch pad, strong crosswinds threatened to call-off the launch. Never-the-less NASA continued with the countdown as planned. The crew entered the orbiter and were strapped in their seats.

Prior to entering Atlantis the three STS-30 Mission Specialists stand on the 195 foot level orbiter access arm at pad 39B. (Left to Right) Mark Lee, Mary Cleave and Norman Thagard. The Mission Specialists were responsible for the deployment of Magellan. NASA

The countdown reached the T-9 minute point where it entered a planned built in hold. As expectedv meteorologists refused to give the 'go' for launch because of cloud near the SLF and the strong crosswinds. If Atlantis had to make a Return to Launch Site abort (RTLS) Commander Walker would have had to land the orbiter on the runway. NASA likes to have the best possible conditions at the SLF because any adverse weather would complicate what is already a very difficult manoeuvre.

Atlantis' launch window had extended to 64 minutes. But this was now being 'eaten up' by the delay. As the window grew shorter, Chief Astronaut Daniel Brandenstein flew the shuttle training aircraft through the clouds above the SLF. He reported back to Launch Control that the clouds were scattered and this part of the weather problem was dismissed. However the crosswinds continued to be unacceptable.

With the launch window drawing to a close, Launch Director Bob Sieck decided to continue with the countdown until the T-5 minute point where it would hold until the weather cleared. It was during this hold and with just ten minutes left in the window that winds dropped to a safe level. The countdown immediately resumed and Atlantis blasted off at 19:47 BST making a flawless ascent. The SRBs were successfully separated and later recovered at sea. (The initial examination of the boosters showed no problems with the joints.) The main engines completed their work and there followed what Commander Walker described as a rather bumpy External Tank separation. Two OMS burns placed Atlantis into a circular orbit of 160 nautical miles.

Continued p.186...

Arianespace Signs its Largest Contract

Arianespace has signed a deal with International Telecommunications Satellite Organisation to launch three Intelsat VII satellites. The deal, worth approximately $317 million, is the largest contact ever awarded to Arianespace.

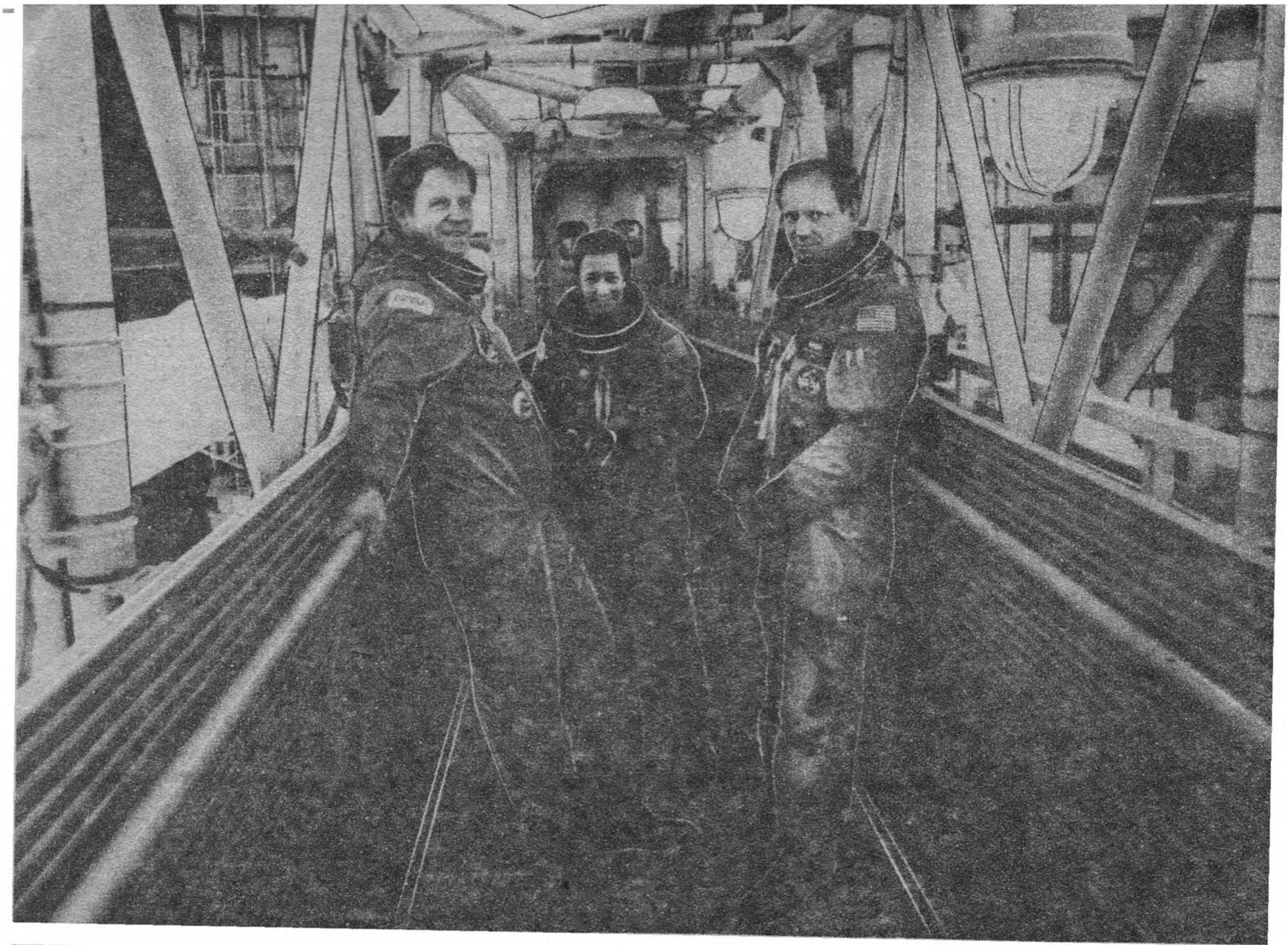
The Intelsat VII satellites are being developed and built by Ford Aerospace Corporation. The satellites are to be launched by Ariane 4: Intelsat VII-F1 in the third quarter of 1992; Intelsat VII-F4 in the fourth quarter of 1993; and Intelsat VII-F5 in the second quarter of 1994.

Ariane V34 is scheduled to launch the Intelsat VI-F1 satellite later this year. Ariane launch vehicles have successfully launched four Intelsat satellites in the past six years.

With this latest contract, Arianespace has now recorded a total of 71 launch service contracts. The company has 35 satellites to be launched, worth $2.35 billion.

- The first Ariane 4 to be equipped with four strap-on liquid propellant boosters was due for launch on April 28, with the Superbird A and DFS Kopernikus-1 satellites aboard. However, the flight was postponed until May 25 due to problems with the cryogenic third stage

(Right) The Superbird satellite during preparations for launch. The DFS satellite is in the background.



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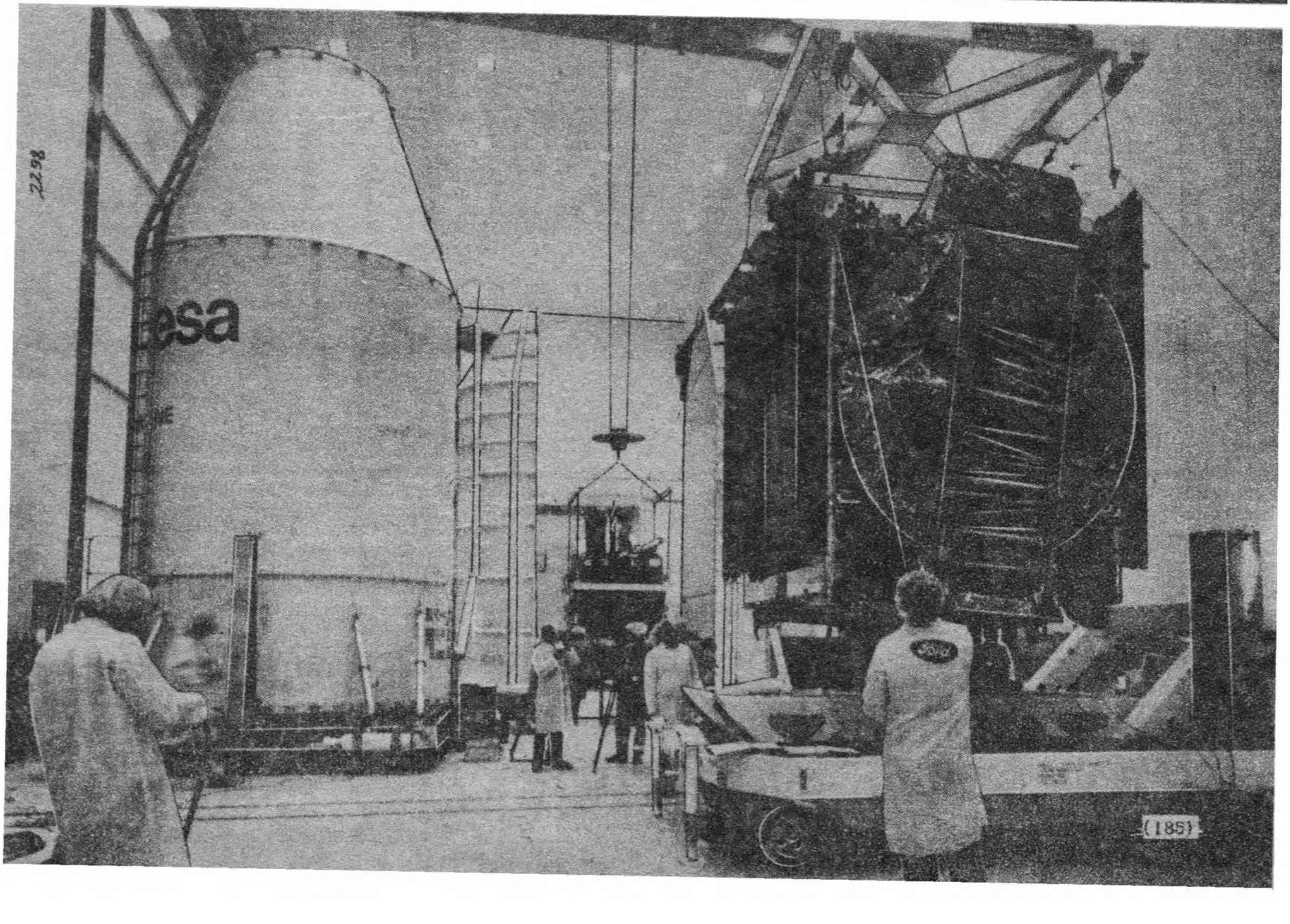

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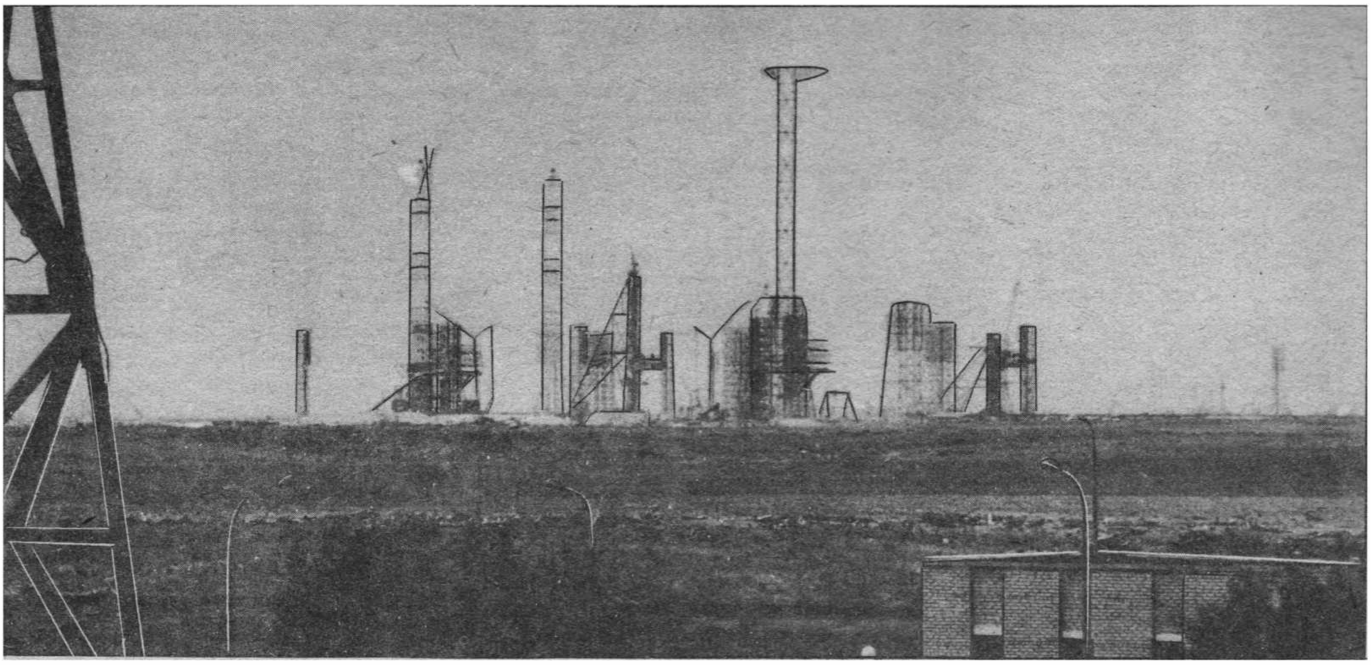
INTERNATIONAL SPACE REPORT



A photograph of the Buran/Energia launch pads at the Baikonur Cosmodrome taken during May 1988. It is believed the left-most launch pad is where the first flight of Buran began. The access and emergency escape chutes can be seen leading into an underground bunker. The 100 metre rotating service tower is in the retracted position, located right of the Buran launch pad. A second shuttle pad can be seen in the centre of the picture. On the right hand side is the Energia-only launch pad from where the booster's maiden flight took place. The photograph will accompany an article by Peter Pesavento, which will appear in the Soviet Astronautics edition of **JBIS**. *Robert Windrem*

Buran - Manned Flight Puzzle

Docking With Mir Planned

The Soviet officials are making conflicting statements about when the Space Shuttle Buran will make its first manned flight. Two Soviet space officials say the manned mission will take place next year. But shuttle pilot Igor Volk does not expect a manned mission until 1992.

Vadim Kravitz, who supervised Buran's first flight, said in January a manned flight of the orbiter would take place "no earlier than in 18 months time". Kravitz said Buran was equipped with a docking unit for Mir and "docking will be part of the first manned missions." Nikolay Kardashev, deputy director of the Space Research Institute, has also said Buran will fly manned next year. He was speaking at a press conference in San Francisco, where he was attending the annual conference of the American Association for the Advancement of Science.

But Buran test pilot Igor Volk has said there are problems with Buran that will have to be resolved before it can fly again. He says the short comings lie in the automatic control system. Buran made some unexpected violent turns before its landing last November, says Volk.

Meanwhile Glavkosmos chief, Aleksandr Dunayev, has said the Soviet Union is not planning a shuttle flight this year. Analysis of the first Buran flight is still underway he added.

The Soviets have revealed the mysterious payload carried by Energia on its maiden flight in 1987 was a mockup of the Buran fuselage minus wings and tailplane. The mockup failed to reach orbit when its third stage fired in the wrong direction. The designers of Energia have said the booster is to become reusable: "Strap-on rockets on the booster's body will be used to help at reentry and permit a soft landing. A parachute system is also provided and cushion supports will be used for landing. The second stage will be fitted with a delta wing to enable it to land as an aircraft."

Continued from p.184.

Magellan Deployed

Six hours 18 minutes into the flight over the Pacific Ocean Mission Specialist Mark Lee operated a switch from Atlantis' flight deck triggering powerful springs to deploy Magellan and her IUS booster. An hour later the IUS motor fired and Magellan began the 15 month journey to Venus. The probe will fire its thrusters on May 21 to correct its trajectory.

With the major task of the mission completed the five astronauts spent the remaining three days of their mission working with the onboard experiments and Earth observation photography.

The crew had to contend with only minor problems during the first half of their flight. They woke on their second day in orbit to high humidity - this was soon corrected and returned to a comfortable level. A camera used for Earth resources photography was rendered useless when its shutter jammed - the crew were unable to solve this problem. The crew's water dispenser would not give an accurate measure of how much water was being injected into dehydrated food so the crew had to use their own judgement.

A commercially available home video camera was tested by Mary Cleave and proved suitable for future use onboard the Shuttle. The crew were able to photograph lightning over Africa as part of the Mesoscale Lightning Experiment.

The crew were confronted by a major problem late in the flight when one of the five General Purpose Computers (GPC) malfunctioned. The five computers have overall control of the Shuttle vehicle and are vital for monitoring the Shuttle's many systems. Although the faulty computer was a back-up it was decided the crew should attempt the first on-orbit replacement of a GPC. The crew successfully carried out the complicated procedure of removing the malfunctioning computer and replacing it with a spare carried onboard the orbiter.

A Flawless Landing

The crew spent their final day in orbit preparing for the return to Earth. Atlantis touched down on concrete runway 23 at Edwards Air Force Base at 20:43:33 BST on May 8. Winds proved favourable for a test of the Shuttle's ability to land in a strong crosswind. Atlantis passed the test with flying colours - boding well for the resumption of Shuttle landings at the Kennedy Space Center.

There was very little tile damage and NASA Administrator-designate Richard Truly said Atlantis was one of the cleanest spacecraft he had seen at the end of a mission. Minor tile damage was caused by rubber breaking loose from the left main landing gear. Overall about 12 tiles require replacement and there are about 100 small repairs which will require attention.

Atlantis was scheduled to be returned to the Kennedy Space Center on May 13 where preparations will begin for her next mission, STS-34, when she will launch the second interplanetary mission of the year: the Galileo probe to Jupiter.

Shuttle Risk High NASA Admits

1-in-78 Chance of Another Disaster

NASA has revealed that each Shuttle flight faces a 1-in-78 chance of 'catastrophic failure'. Such an accident would involve loss of the orbiter and possibly the astronauts as well. NASA is continuing its work to improve Shuttle safety and plans to transfer many payloads to unmanned launchers.

NASA's grim assessment of Shuttle safety is in contrast to the agency's optimistic beliefs before the Challenger accident when NASA quoted the chances of disaster as 1 in every 100,000 flights. At the same time the US Air Force was offering a more realistic evaluation of Shuttle safety. It believed a failure of a Solid Rocket Booster was most likely, with a possibility of 1-in-35.

A more safety conscientious NASA is now willing to accept the possibility of another disaster. James Thompson, the head of NASA's Marshall Space Flight Center, said the agency needed to avoid complacency after its recent successes and should continue to find ways to reduce risk.

"We shouldn't rest on any laurels after three launches," Mr Thompson said. "There are going to be failures in the future, and we should try to minimize that" by further improvements to the Shuttle, he said. "But NASA has to avoid the trap of saying all flights are going to be successful. That's just not on the cards."

Benjamin Buchbinder, manager of safety risk assessment at NASA Headquarters, said the 1-in-78 estimate was statistically the most probable, with the estimate's range of reliability extending as high as 1 flight in 168 and as low as 1-in-36.

It should be noted that although the Shuttle orbiter would be lost in the above scenarios, the crew might survive. For example a multiple main engine failure during the first few minutes of flight would result in a ditching at sea, but the crew could bailout before the fatal crash.

Ariane 2 Goes Out in Style

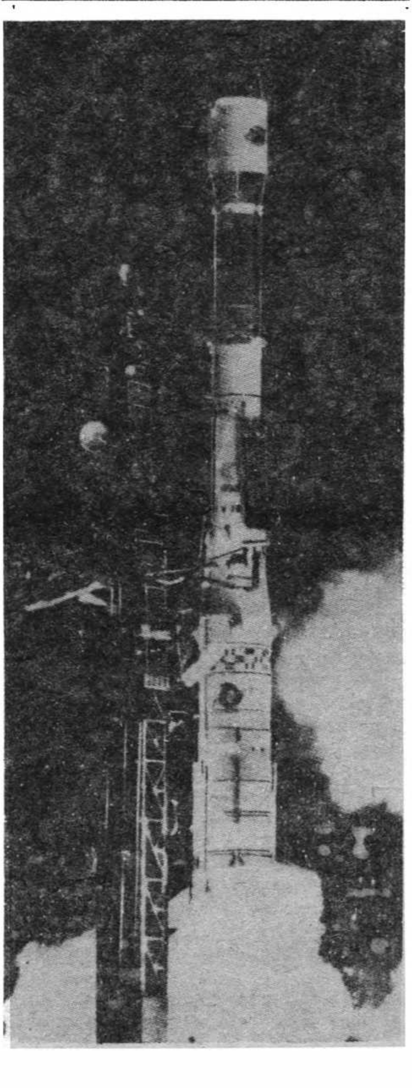
The final Ariane 2 blasted off from launch pad ELA-1 on April 2 carrying the Tele-X telecommunications satellite. The satellite was placed almost precisely in the designated orbit about 17 minutes after launch.

Tele-X is of the same design as the French TDF-1, but in addition to direct broadcasting it features commercial communications for video conferencing, video data transmission, and computer links. Tele-X was built for the Swedish Space Corporation by the Eurosatellite team (Aerospatiale, Alcatel-Espace, MBB, ANT, AEG and ETCA) and with the contribution of the Swedish firms, Saab and Ericcson. Tele-X is designed to serve Sweden, Norway and Finland.

The satellite, launched at 0228 GMT on April 2, was placed in the following initial geostationary transfer orbit:

Apogee: 35,979km ($\pm$ 100km) for 35,992km intended
Perigee: 250km ($\pm$ 1km) for 249.7km intended
Inclination: 3.96 ($\pm$ 0.005) degrees for 4.0 degrees intended

Tele-X reached its assigned position in geostationary orbit of 5 degrees East on April 14.



(Right) The final Ariane 2 blasts off from launch pad ELA-1 at 0228 GMT on April 2. *Arianespace*

DoD Cuts NASP Funding

After pressure from the White House, US Defense Secretary Richard Cheney has reversed his earlier decision to stop Department of Defense funding for the National Aerospace Plane (NASP). However, the DoD contribution to the project of $300 million has been slashed to $100 million. NASA intends to provide an additional $127 million for NASP. Meanwhile the US National Space Council has begun a review of the project and until it presents its findings NASA will have overall control of NASP.

Radars in Space

Marconi Space Systems has been awarded a contract by the UK Ministry of Defence to study space based surveillance radars. The aim of the study is to evaluate candidate radar solutions and to specify a space system capable of meeting any future UK operational requirements. Radars installed in satellites are uniquely able to provide 24 hour, all weather surveillance of immensely larger areas of the Earth's surface than are possible from ground or airborne systems, and can thus provide the earliest possible warning of potentially hostile situations. They also offer advantages in some civil applications, particularly in air traffic control, in areas which cannot be covered by ground based radars.

• Marconi Space Systems are providing the prime sensor, the Synthetic Aperture Radar, for Europe's first remote sensing satellite ERS-1, which will provide all-weather Earth observation of sea, coastal and land regions.

Brazilian Space Chaos

A dispute in Brazil over the launch of the first Brazilian satellite demonstrates the ambiguity of the Brazilian space organisations, writes *Theo Pirard.* The National Space Research Institute (INPE) supports a launch agreement with China for the use of a Long March 2, while the military Institute for Space Activities (IAE) favours the indigenous Satellite Launch Vehicle of Brazil (VLS). The VLS programme is suffering some technological delays. Meanwhile, the INPE's MECB satellites are taking shape and will be ready for launch in 1990...

Hauck Takes Navy Post

Astronaut Frederick "Rick" Hauck, veteran of three shuttle flights, left NASA in April to take up the post of Director of the Navy Space Systems Division at the Pentagon. "My 11 years with NASA have been extremely rewarding," Hauck said. "I am looking forward, however, to continuing my career in the Navy and to the new challenges it provides."

Space Station Robot Contract

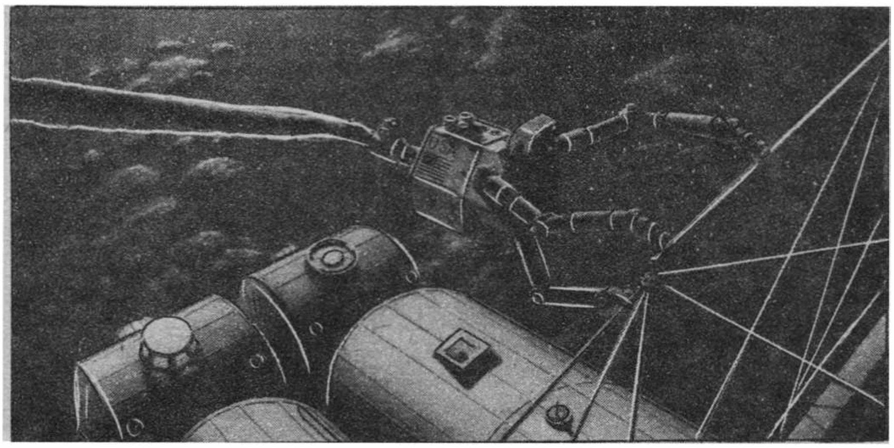
Martin Marietta Space Systems has won the contract to develop and build the Flight Telerobotic Servicer (FTS) which will assist in the assembly and maintenance of the Freedom Space Station.

Under the $297 million contract the company will provide a prototype FTS for testing during two shuttle missions and a final operational version for the Space Station.

The FTS will enable astronauts to direct routine assembly and maintenance work without leaving the Space Shuttle or Space Station, thereby enhancing crew safety. The FTS will be equipped with multiple, highly dexterous robotic arms, advanced control systems, and video cameras for viewing. When Space Station assembly is complete, the FTS will use artificial intelligence, which will enable the computer to "think" like a human to perform tasks.

The FTS will be launched in the mid-1990s aboard an early Shuttle flight ferrying Space Station equipment to orbit. For Space Station assembly operations, the FTS will be attached to either Space Shuttle or Space Station remote manipulator arms, with crew members inside the Space Shuttle or Space Station directing FTS operations. FTS tasks for Space Station include installing and removing truss members, installing fixtures on the truss, changing orbital replacement units, mating thermal utility connectors, and performing inspection tasks.

Eventually, NASA expects the system to perform complex tasks with a single command. As the Space Station develops the ability to service satellites and large space instruments, the robot would be used to minimise crew involvement. For example, large space instruments like NASA's Hubble Space Telescope would be brought to the Space Station's servicing facility where the servicer would perform autonomous functions like replacing telescope components.



An artist's impression of the FTS at work outside the Freedom Space Station. *Martin Marietta*

Greens Spike Sunlight Project?

By Brian Harvey

A five-year-old Soviet plan to light up the night sky with giant space mirrors has been deferred for some time, it has been learnt in Moscow. The plan has fallen victim to the growing power of the "green" movement for environmental protection in the USSR.

The project was conceived in the early 1980s. The intention was that satellite reflectors would beam down light to illuminate parts of Siberia during the prolonged periods of winter darkness. One idea was to light up oilfields, thus making feasible the winter working of the oilfields. The project opened up prospects for increasing industrial output in a number of areas.

Energia

The project is by no means dead, but it has now been put off until the "completed" Energia rocket is ready to launch the large payloads required. As a result, experts say, it is now "probably a project for the next century" [1].

Ecologists are increasingly concerned about the general brightening of the Earth's atmosphere, it has been learnt. Astronomers also fear it will impede their access to the heavens. "There is also the problem of directing the light at selected targets and localising its effect. All this is being carefully studied. With the growing ecological awareness of the nation, no unsound project could receive the go-ahead" [2]. Other objections have revolved around the unpredictable consequences that might ensue should permafrost be melted.

Advocates of the concept explain that a solar power satellite high above the Earth would not be eclipsed by the Earth's shadow. Instead, using reflectors and mirrors, it could beam down light onto towns, streets, and transportation centres. Savings on electricity would be considerable and would come from a "clean" source.

Small Demonstration Satellite

Work on a small, experimental demonstration satellite began in early 1984 at the Moscow Aviation Institute and reached an "advanced stage" in May of the year. A 200kg satellite was to deploy a reflector 110m^2 across which would illuminate an area of 9km^2 to a brightness 50% greater than the full Moon. The experiment was expected to pave the way for an operational system by 1994 [3].

The satellite never flew. At the very time that it was being prepared for launch the USSR Academy of Sciences set up a committee to investigate the possible ecological effects of the sunlight-by-night scheme [4].

The demonstration satellite was to precede much more ambitious projects. "It is intended to be the forerunner of larger reflectors which could light a whole city or construction project at night with sunlight seven times brighter than a full Moon. Free illumination of five cities the size of Moscow would save enough electricity to repay the cost of the space reflector within four or five years" [5].

Pravda in November 1983 revealed that Soviet scientists were "already working" on the night-time lighting of the Arctic Circle region [6]. The EVA assembly work just then completed by Salyut 7 cosmonauts Vladimir Lyakhov and Alexander Alexandrov was heralded as opening the way for the type of assembly tasks that would be involved.

Grandiose Project

The experimental satellite seems to have progressed no further, and the plan now seems to have been put well down the line [7]. The Chernobyl accident, Glasnost, the new-found political clout of the Soviet ecological movement, and a healthy distrust of the grandiose (and ecologically suspect) schemes of the Brezhnev era may well keep it there.

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Water Power for Space Station

A team of workers in the Propulsion and Power Division at the Johnson Space Center (JSC) is developing a propulsion system - fuelled by water - that will prevent the orbit Space Station Freedom from decaying.

A prototype of the propulsion concept, which separates water into its tow components, hydrogen and oxygen, and then uses them as propellants, is now being tested. Although the test system is far different in size, appearance and construction from what eventually may fly, the processes used are identical. McDonnell Douglas will eventually build the flight hardware.

A system of 24 thrusters will be needed at least four times a year to boost Space Station Freedom back to its proper, 220 nautical mile-high orbit. Using water as the raw propellant for such a system is uncharted ground, but it's an idea that makes sense.

The shuttle uses monomethyl hydrazine and nitrogen tetroxide, two chemicals that ignite on contact, to propel it in space. But the space station's system will break down water into hydrogen and oxygen by electrolysis.

If a traditional propulsion system such as the Shuttle's were used on the space station, propellants would have to arrive by special delivery. But with a water-based system, excess water that is now dumped as waste during each Shuttle mission can be used to refuel the station. Water is a byproduct of the Shuttle's power cells which combine hydrogen and oxygen to create electricity - the opposite of electrolysis. The amount of water created during each flight is much more than is needed by the crew and normally is dumped overboard.

"Every time a Shuttle goes up, the excess water can be transferred to the station," Don Blevins, assistant for programme management in the Propulsion and Power division, said. "It's basically a free resupply that way." Waste will be eliminated.

"We can save on the amount of propellants that have to be brought up to the station," he said. "And it can save a significant amount of money over the 30-year life of the programme."

The concept for the water-based thrusting system is new territory for several reasons, among them its complexity, extended lifetime and limits in weight and volume, Blevins said.

Once the electrolyzer separates the water into hydrogen and oxygen, the two gases remain saturated with water vapour and must be dried before they can be used as propellants, said Rex Delventhal, an engineer in the Propulsion Branch. First the gases go through phase separators, cylindrical tanks that allow the heavy water vapour to sink to the bottom. Then the gases are channelled into desiccant material dryers, that work using water absorbent materials.

The propellants are stored in tanks at a pressure of 3,000 pounds per square inch. The hydrogen and oxygen remain in gaseous form and burn as gases in the thruster, a major difference between other rocket engines that use propellants in liquid form, Delventhal added.

The test system has been working well, and tests appear to be proving the feasibility of the system, Blevins said. Two thrusters will be tested on the system, one built by Bell and another by Rocketdyne. The Bell thruster has been fired seven times so far in tests, the longest of which was a 12-second burn. Next the Rocketdyne thruster will be tested.

Once the series of tests is completed, work will begin on a Phase B system that will more closely resemble what may fly. The future testing will involve firing two thrusters simultaneously.

When it flies, the system must be capable of firing thrusters for a one and a half hour burn four times each year, each time boosting the space station from 10 to 15 miles higher. Without it, the station's orbit would eventually decay.

The thrusters need to have a functional life of about five years, Blevins said, which means at least 20 hours of use But the system also must be capable of milliseconds-long bursts to control and stabilize the station's altitude

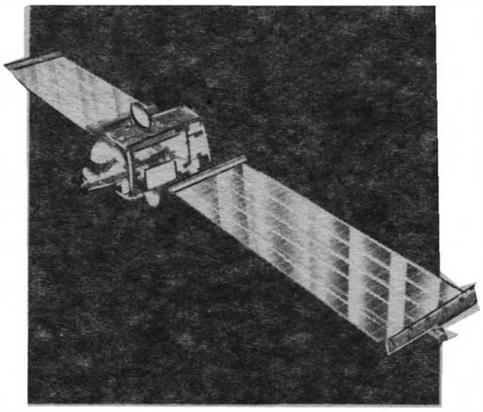
Olympus 1 Arrives in Kourou

The Olympus 1 communications satellite, built by a consortium of aerospace companies led by British Aerospace (Space Systems) Limited, has arrived in Kourou, French Guiana where it will be prepared for launch by Ariane in June 1989. When in orbit, Olympus 1 will be the world's most powerful civil communications satellite.

Prior to shipment, Olympus 1 successfully completed a series of rigorous environmental and mechanical tests undertaken at the David Florida Laboratories and at the National Aeronautical Establishment in Ottawa, Canada.

A specially chartered Belfast transport aircraft carried the satellite from Ottawa to Kourou. Test and check out equipment were transported by a Boeing 747 freighter - its cargo hold too small to accommodate the satellite. The body of Olympus 1 measures 2.9 m (9ft 6in) wide and is 5.5m (18ft 2in) high. In orbit its solar arrays measure 25.6m (84ft) from tip to tip - half the width of a football pitch.

Olympus 1 carries four separate communications payloads which will assist in the development of new communications services within Europe. Payload applications include high power direct broadcast TV, video conferencing, data transmission and tele-educational services.



Artist's impression of the Olympus communications satellite in orbit. *BAe*

Olympus 1 was built under contract to the European Space Agency as a technology demonstrator for a future class of large and powerful communications satellites. Future Olympus satellites could have solar arrays measuring up to 56m (184ft), providing up to 7.7kW of electric power-enough to power 40 channels of direct broadcast television or up to 250,000 simultaneous telephone calls.

Contract Follows Skylark Success

British Aerospace has received a contract valued at £1.5 million to supply the German Company MBB-ERNO with a further six Skylark Sounding Rockets, so extending one of the world's longest and most successful space programmes.

The six new rockets will be launched from Esrange, Sweden over the next three years as part of the MBB-ERNO microgravity programme. The two stage solid propellant powered rockets will carry modular payloads up to altitudes of 250 kms. At this altitude the payload module separates from the rocket and experiences six minutes microgravity time before returning to Earth by parachute. The payload is then recovered by helicopter for delivery to an on-site laboratory.

Typical experiments undertaken in weightlessness conditions include the study of crystal growth, biotechnology and the melting of metals.

This latest contract award follows the successful launch of the 410th Skylark Sounding Rocket on February 10, 1989, from the Esrange Rocket Range, near Kiruna, northern Sweden. This was the fourth Skylark Rocket to be launched as part of the German ROSE (Rocket Scatterometer Experiment) programme investigating the relationship between the solar wind and the Earth's atmosphere - the phenomenon known as the aurora borealis. Since the start of 1988 there have been nine consecutive Skylark launches, all of which have achieved mission objectives. The first Skylark was launched in February 1957.

Briton in Space

The signing of the agreement to launch the first Briton in space onboard a Soviet Soyuz capsule has been postponed. The agreement was due to be signed at Moscow Airport on April 14. But at the last minute the ceremony was cancelled It is now believed the agreement will signed in June when UK Minister Lord Young is visiting Moscow.

SATELLITE DIGEST - 222

Robert D. Christy

Continued from the May 1989 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

ASTRA 1A, 1988-109B, 19688

Launched: 0033*, 11 December 1988 from Kourou by Ariane 44LP.
Spacecraft data: Three-axis stabilised, box-shaped body, 3.18 x 2.03 x 1.52 m, with an aerial array on one face. Power is provided by a 19.3 m span solar array. The mass (in orbit) is 1045 kg.
Mission: Television broadcasting satellite, equipped with sixteen operational, and six spare, transponders.
Orbit: Geosynchronous above 19 degrees west longitude.

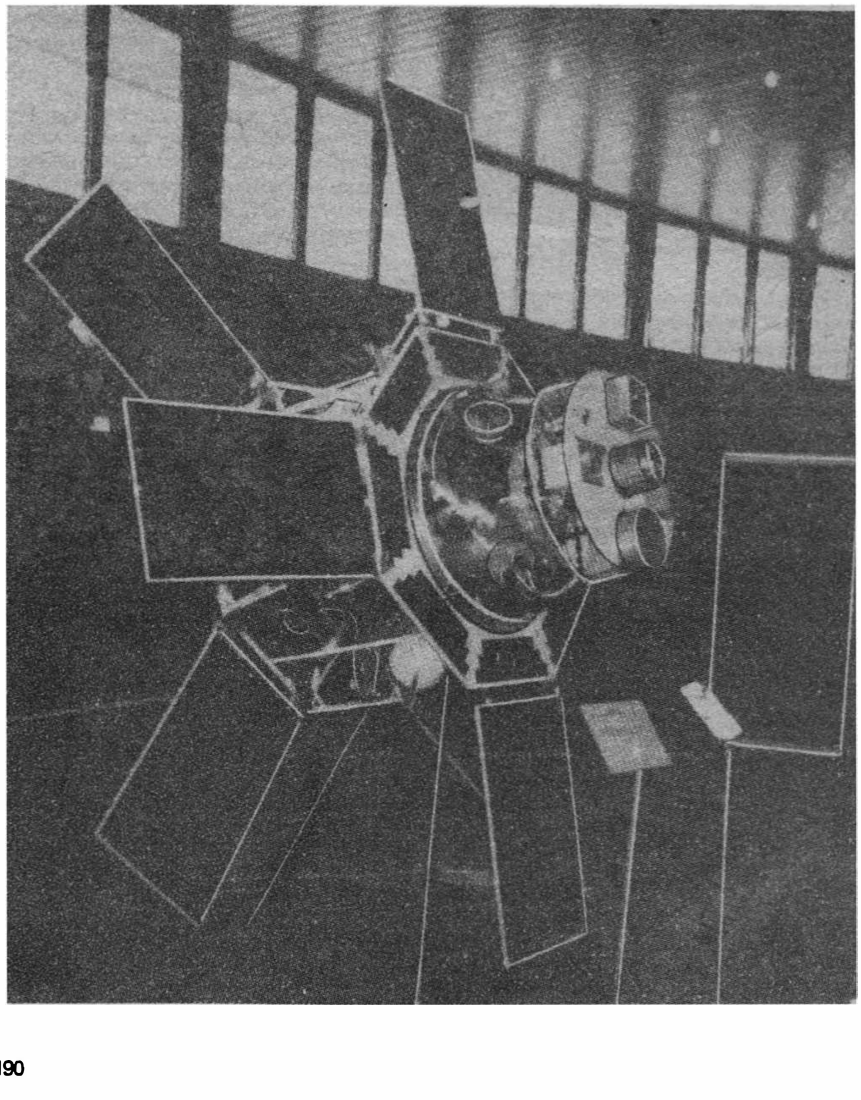
COSMOS 1984, 1988-110A, 19705

Launched: 1900, 16 December 1988 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period, reentered after 59 days.
Orbit: 188 x 325 km, 89.64 min, 62.85 deg, manoeuvrable.

CHINA 25, 1988-111A, 19710

Launched: 1240, 22 December 1988 from Xichang by Long March 3.
Spacecraft data: Cylindrical, spin-stabilised body with de-spun aerial.
Mission: Communications satellite.
Orbit: Geosynchronous above 110.5 degrees east longitude.

A Molniya communications satellite photographed at a Soviet space exhibition recently held in Budapest, Hungary.
N.Schuminszky



MOLNIYA-3 (34), 1988-112A, 19713

Launched: 1416, 22 December 1988 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 432 x 39056 km, 700.27 min, 62.80 deg, then raised to 444 x 39889 km, 717.35 min, 62.79 deg, to ensure daily repeats of the ground track.

COSMOS 1985, 1988-113A, 19720

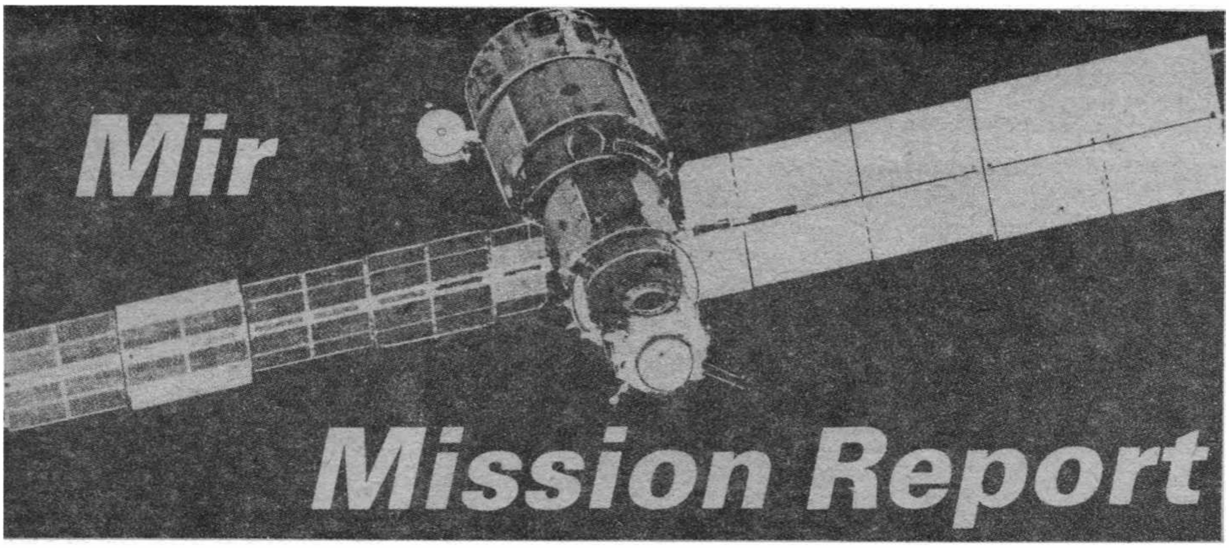
Launched: 1030, 23 December 1988 from Plesetsk, by F-2.
Spacecraft data: not available.
Mission: Military satellite, used to test ground-based missile-tracking radars.
Orbit: 526 x 534 km, 95.28 min, 73.57 deg.

PROGRESS 39, 1988-114A, 19728

Launched: 0412*, 25 December 1988 from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carrying a rendezvous radar tower, a covered liquid tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried equipment and consumable supplies to the resident crew of Mir. It docked with Kvant's aft-facing hatch at 0537 on 27 December. It undocked at 0646 on 7 February 1989 and was de-orbited later the same day.
Orbit: Initially 187 x 237 km, 88.7 min, 51.63 deg, then by way of a 237 x 338 km transfer orbit to a docking with Mir in an orbit of 325 x 353 km, 91.26 min, 51.63 deg.

MOLNIYA-1 (74), 1988-115A, 19730

Launched: 0529, 28 December 1988 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 637 x 38859 km, 700.45 min, 62.82 deg, then raised to 617 x 39736 km, 717.75 min, 62.85 deg, to ensure daily repeats of the ground track.



Cosmonauts Leave Mir Unmanned

When cosmonauts Volkov and Krikalev blasted off from their launch pad at the Baikonur Cosmodrome they were looking forward to an ambitious six month mission on board the Mir space station. Together with Dr. Polyakov, who was launched to the station in August 1988, they were to make two space walks and receive the space station's first 20 tonne add-on modules. Unfortunately things did not go to plan and the cosmonauts returned to Earth, without making the space walks, leaving the station empty for the first time in over two years and without the new modules having docked. Regular *Spaceflight* correspondent *Neville Kidger* has the details. He begins by bringing us up to date with the work carried out since the end of last year.

By Neville Kidger

Progress 39

The unmanned cargo craft Progress 39 docked with the Mir complex at 0535 (all times GMT) on December 27, 1988 after being launched from Baikonur two days previously. It delivered over 1,300 kg of cargo for the resident Donbass crew - Aleksandr Volkov, Sergei Krikalev and Dr. Valeri Polyakov.

Surprises for the three men included fresh fruit and vegetables and New Year gifts from their families.

The cosmonauts were the latest in the succession of resident and visiting crews to stay on the Mir/Kvant complex. But for the Donbass crew their stay was to be a significant one.

At the pre-launch press conference, Volkov had told reporters that the crew were to return in late April having received three Progress cargo ships, a new module and two EVA's by Krikalev and himself. The first month of the mission had already passed very eventfully with six cosmonauts on the complex, including Frenchman Jean-Loup Chretien.

There were few reports of the cosmonauts' activities over the New Year period but on January 2, 1989 they began a new series of Earth observations studying the natural resources of Siberia and the Soviet Far East.

Over the next few days the men also conducted several sessions of astronomical observations using the Bulgarian-made Rozhen system. An experiment named Polarizatsiya involved photometric observations of stars, galaxies and nebulae. Using the Bulgarian-made Parallax-Zagorka instrument the men observed the vertical distribution of luminescence in the polar, middle and equatorial latitudes of Earth and also the luminescence of the complex itself which results from the interaction with the atmosphere. Similar experiments were conducted on the US Shuttle to observe the glow given out from the spacecraft as it interacted with molecules of atomic oxygen in the rarefied atmosphere in orbit.

Ultraviolet pictures were taken using the Glasar telescope located in Kvant. Several areas of the constellations Auriga, Cassiopia, Orion and Vela as well as the X-ray observation of sources in the Vela constellation and the Small Magellanic Cloud. The X-ray telescopes were also located on the Kvant in an unpressurised section.

Medical tasks were also being undertaken on a regular basis under the supervision of Dr. Polyakov, who had joined the Mir crew in August 1988. These tests included extensive examinations of the men's cardiovascular systems using equipment provided by Soviet and French scientists.

On January 17, amidst the reports of routine technical replacement work, the Soviets announced that preparations were underway for the EVAs. The next day, at a press conference in Moscow, Glavkosmos chief Aleksandr Dunayev told reporters that the launch of the new module would now occur within the first six months of the year. This was the first official indication of the problems which were to disrupt the pre-announced plans for the Mir complex.

Continued Routine

One of the pieces of equipment being used by Dr. Polyakov in his work was a rapid blood analyses. The device, called Retroflon, was developed by the West German firm Boehringer Mannheim and was another indication of the growing commercial cooperation between the Soviets and the rest of the world. The commercialisation of the Soviet programme is bringing about some interesting developments (to be discussed later).

On January 24 TASS announced that the complex's orbit, which had been adjusted by Progress 39, was currently at a height of 376 x 340 km with a period of 91.4 minutes and an inclination of 51.6 degrees.

The cosmonauts were using a holographic gauge to check the optical properties of the portholes. It had been reported by earlier crews that the portholes had begun to collect a fine film of dust - some of which was wiped off during EVAs by the year-long-stay crew of Vladimir Titov and Musa Manarov.

Between January 24 and 26 the Soviets reported that the men were replacing a control in the thermoregulatory system with a new one delivered by Progress 39. After installing it they checked for leaks in the hydraulic line. Such repairing and replacement work is a large part of the cosmonaut's work in orbit.

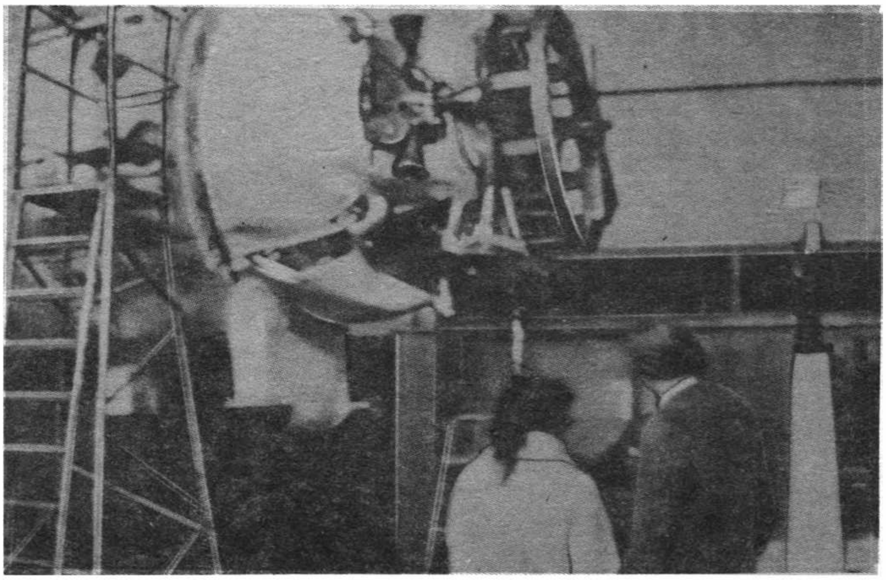
As January slipped away, the cosmonauts continued their routine. The Flight Control Centre often controls the orientation of the complex to use the Kvant X-ray telescopes to observe sources. Even as the cosmonauts slept the complex was oriented to view the southern constellation of Circinus to examine an X-ray source thought to be a double star.

In one of the first such descriptions for a while, the Soviets described a new technological experiment being conducted by the Donbass crew. The Yantar equipment was installed in the complex's airlock to obtain metal coatings in weightless conditions. A dual component alloy of silver-palladium and tungsten-aluminium was applied to a polymer film. Such experiments were conducted regularly on the Salyut 6 and 7 stations using a device called Isparatel.

Beginning February 1, the Soviets said, the crew would begin visual observations of Soviet territory on a regular basis because the complex was beginning overflights of the country during daylight periods.

Another Setback

In early February Soviet radio revealed



Forward view of the 're-equipment' module at the Star City training centre. The one metre diameter airlock and a group of thrusters are visible. *Central News*

the EVA planned for February had been scrapped. No reason was given at the time for the cancellation but it was later to emerge that the launch of the building block modules slipping to later in 1989. On being told of the delay and the fact that his crew would not receive the first module, Volkov reportedly said "technology is technology." Another source said a new crew would be launched in April and were to be replaced six months later.

Earth observations, experiments with the Yanter installation and medical tests occupied much of the first days of February. The Earth observations were supplemented by pictures obtained from an unnamed Cosmos satellite.

At 0646 GMT on February 7 Progress 39 was undocked from Kvant and was deorbited to destruction at an unspecified time later that day.

Another series of UV photography sessions was begun on February 8 with the first target being the constellation of Taurus.

Another Progress

At 0854 on February 10 the 40th Progress cargo ship was launched from Baikonur. It docked with the Kvant port two days later at 1030. Western sensors tracked the complex in an orbit of 364 x 347 km after the docking. The cosmonauts began unloading the various cargoes the next day as they continued their Earth observation experiments and astrophysics work.

During February 14 Aleksei Leonov told reporters in Moscow that the Volkov crew was to be replaced by the end of April. The next crew would "most probably" be commanded by Aleksandr Viktorenko.

Viktorenko was the reserve commander for Soyuz TM-7, which launched Volkov, Krikalev and Frenchman Chretien. His flight engineer on that occasion was Aleksandr Serebrov.

Serebrov had been training for an EVA from the new module using the one metre diameter forward hatch. He was to try out the Soviet version of the manned manoeuvring unit which had been shown to an international corps of reporters the previous November at Baikonur. The initial flight at least of the new unit would see Serebrov anchored by a tether to the Mir complex. The cord would be a nylon one with a metal core which could be severed in an emergency, Soviet officials told a Western reporter.

The Americans had practised flying a prototype of their MMU in an untethered mode but that was within the confines of the Skylab space station in 1973.

Leonov's statement did not mention Serebrov and gave rise to Western speculation that he had been dropped from the crew until the new module was launched. This speculation proved well founded when, after returning from Baikonur from a filming trip, the US analyst James Oberg revealed that he had met the Soyuz TM-8 flight engineer - a rookie called Aleksandr Balandin.

Leonov also revealed that the mission planners were unsure whether or not to return Dr. Polyakov to Earth. If he remained on the complex through the planned six-month long flight beginning in April he would have exceeded the year-long record of Titov and Manarov.

One Western analyst suggested Polyakov might wish to remain on the station rather than return and face another painful bone marrow operation. Prior to the TM-6 launch both Polyakov and his backup, Dr. German Arzamazov, had undergone painful bone marrow surgery to enable pre-and-post-flight comparisons to be made.

Tass announced on February 18 that the replacement crew would be launched on April 19.

Future Plans

The third anniversary of the launch of the Mir base block saw a number of interviews relating to the future of the complex.

Viktor Blagov, the deputy flight supervisor, said that the Mir complex would eventually have six spaceships or research laboratories. Kvant was already at the complex. A Soviet drawing released in 1987 had shown two Salyut-class and two Kvant-class modules docked at Mir's front docking unit. A new version reportedly shows four of the Salyut-class modules.

Blagov also said that it was planned to attach independent pointing platforms to the exterior of the complex on which telescopes or other sensors could be mounted. Such pointing systems would enable great savings of fuel on the complex.

TV pictures were shown of the "re-equipment" module at Baikonur and a second module, which the Soviets called "Optizont", undergoing final tests in the workshop.

Chief spacecraft designer Yuri Semenov told TV viewers that the first module was to be launched in the second half of 1989 and that between July and September the module would be equipped with the manoeuvring units. The second module would be launched shortly afterwards (so that symmetry could be retained for manoeuvring).

The second module, a space "factory" would grow crystals for the electronics industry and process biotechnological materials. The yield of the module would be about 100 kg of produce per year, Semenov said, after it had begun work in late 1990 or early 1991.

The designer said that Mir had already recouped 25 per cent of its costs to date. The new technology module would earn 1,000 million Roubles per year which would be "many hundreds of millions" of Roubles in profits.

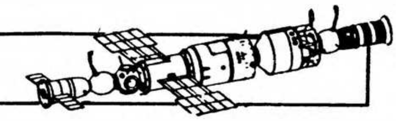
The delay in launching the technology module may have been attributable to the development time of ecological monitoring equipment which it was to carry. The violation of announced plans was a "disease which we have in many, many cases... [which] also happens in the space branch," A Soviet journalist said. "Somehow we have never talked about this before."

Meanwhile, in orbit, the three man crew had been assigned an increased work load of experiments. One of these was Diagram in which measurements of the physical characteristics of the atmosphere were conducted using a magnetic-discharge transducer deployed outside the station's airlock by a rod. The experiment would help evaluate aerodynamic drag.

On February 23 the cosmonauts celebrated Soviet army and navy day by toasting Volkov, a Colonel in the Soviet Air Force. The men were allowed an "exotic" choice of foods - pickled cucumbers, fresh fruit, sweet-smelling Russian bee honey and others - which had been delivered by Progress 40. The menu for the Mir cosmonauts now includes about 70 dishes but excludes alcohol, the Soviets say.

TASS reported that Polyakov had reported that he had dreamed about his family. The agency said that cosmonauts tended to dream about earthly things such as home and family and rarely about space. The agency reported that studies at the Soviet Health Ministry's Institute of Biomedical Problems had discovered that cosmonauts - and most scientists and technocrats - dreamt in black-and-white whilst spiritual people tended to have colour dreams.

MISSION REPORT



Progress 40 Departs

The low key coverage of the cosmonauts' activities continued to the end of February. The men continued Earth observations and medical examinations.

On February 24 the orbit of the complex was adjusted by Progress 40's engine so that the height of the complex above the Earth varied from 396 x 358 km with a period of 91.7 minutes. Refuelling of Mir's tanks was conducted at the end of February. On March 2 the Soviets said that the cosmonauts were filling the cargo ship with used equipment - a sure sign of the craft's imminent departure.

Sure enough, at 0146 on March 3 the cargo ship undocked and slowly separated from the complex. The undocking differed from the standard procedure when two large-sized multi-link folded structures on the side of Progress 40 unfurled one after the other.

The structures resembled an orange segment but more sharply angled than an ellipse. The "unique alloy" which was built into the structures enabled the structure to "remember" its original form. The deployment was achieved by heating up wire leads electrically to stretch the structure like a muscle.

Volkov's crew took still and video pictures of the experiment which, the Soviets said, could find application on future large-scale structures in space. One specifically mentioned use involved covering such structures with reflectors to reflect the Sun's rays to Earth. A more earthly use could involve opening and closing shutters on greenhouses as the temperatures fluctuated.

Progress spacecraft have often been used for experimental work. In 1985 the Soviets launched Cosmos 1669 which they described as similar to the Progress ships. The craft docked with Salyut 7 and performed a mission identical to that of a standard Progress cargo ship. At the end of its flight it undocked from the Salyut 7 station, backed away and then re-docked to confirm the reliability of the docking system, according to an American source. A similar experiment was conducted with Mir by the Progress 32 ship in 1987. This raises the question about the designation of Cosmos 1669 (which one contemporary Soviet report called Progress 25). Perhaps, with the onset of openness, the Soviets may reveal why cosmos 1669 was so designated.

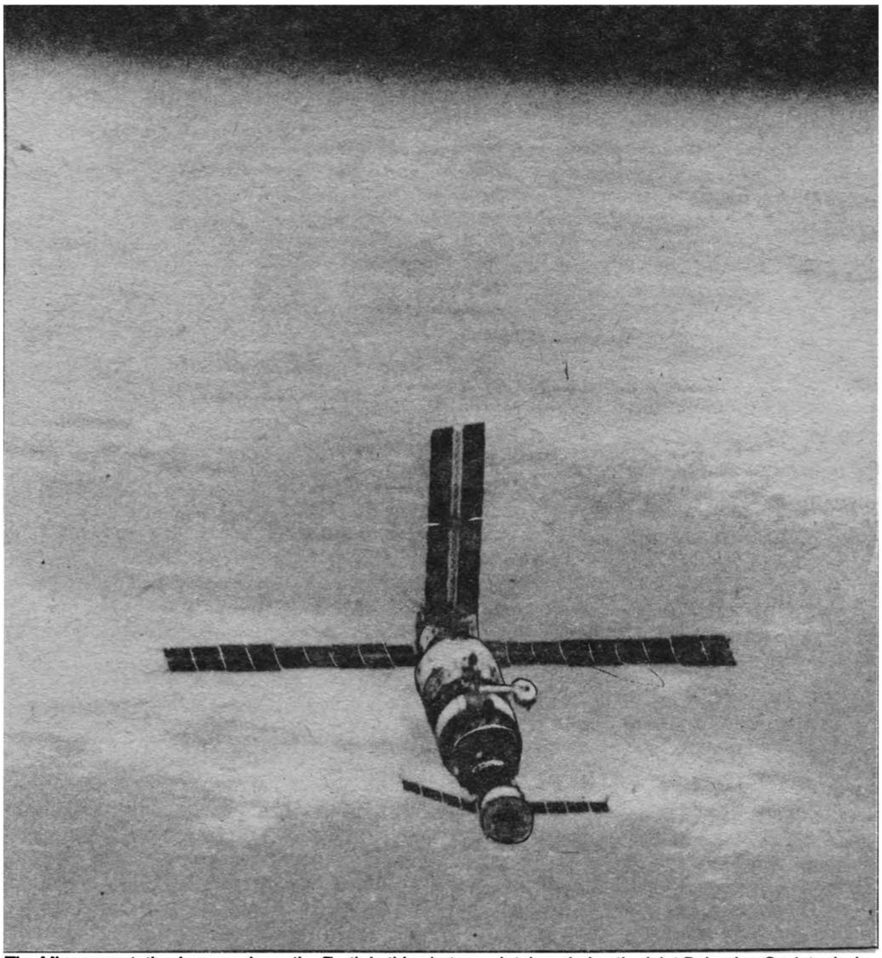
At 0108 on March 5, after two days of autonomous flights and tests of the structures, Progress 40 was deorbited to a destructive reentry.

More Astrophysics

Over the following week the cosmonauts laid emphasis on work with their astrophysics instruments. The mission was said to be entering a new stage in the UV photography with the Glasar telescope.

Readings of the charged particle environment in the complex were taken on a regular basis with the magnetic spectrometer Mariye. One specific task for the device was to register the intensity of high energy particle flows to assess if these were related to areas of seismic activity on Earth.

On March 16, the cosmonauts and ground controlled began a four-day-long cycle of X-ray observations of the central part of our galaxy.



The Mir space station is seen above the Earth in this photograph taken during the joint Bulgarian-Soviet mission of last year. The Soyuz TM-5 is docked to the Kvant module. *Novosti*

Progress 41 In Space

At 1854 on March 16, the third Progress cargo ship scheduled to resupply the Donbass crew was launched from Baikonur. Progress 41 docked with the Kvant port at 2051 two days later. The complex was tracked by Western sensors in an orbit of 363 x 349 km.

On March 20 the unloading of the cargoes began. A highlight of the work over the next few days was the use of the Bulgarian-made Spektr-256 spectrometer to scan the Earth's atmosphere in 256 wavelengths and measurements of the radiation levels in the complex with the French made Circe device.

Sunday March 26 was a historic day in the USSR with elections being held for the newly formed Congress of People's Deputies of the USSR. Successful candidates would include cosmonauts Valeri Ryumin, Svetlana Savitskaya and Viktor Savinykh. Many of the candidates stressed the curbing of expenditure on space ventures in the manifestos. The Donbass crew registered their votes by radio to the FCC who then passed their preferences on to the cosmonaut's constituencies.

TASS chose the same day to reveal how bureaucracy had reached Mir. Sergei Krikalev revealed that he had been served several written orders demanding that he report to a district army draft centre even though he was in space. TASS chided the "dim-wit bureaucrats" who had followed regulations to serve the order. Krikalev, the youngest Soviet cosmonaut in a quarter of a century, said that he was not prepared to return to Earth early. The mission was scheduled to end on April 29.

As March ended, the crew conducted yet more Earth and stellar observations. The cycle continued during the first days of April. One of the Earth observation aims was environmental monitoring of the northern Caucusus and areas adjoining the Black Sea and the Caspian Sea as part of a Soviet-block programme.

On April 4, TASS, in a regular statement, said the cosmonauts were to replace a number of power supply instruments, the warranty period of which was expiring. These had been delivered by Progress 41.

A Shock Report

Special attention was being paid to radiation levels, the Soviets said. This was because high solar activity was causing radiation levels to increase and cause spectacular displays of aurora. The Soviets reported that the men in space were in no danger because the levels were "not hazardous".

On April 10 Progress 41's engines were used to boost the orbit of the complex to 400 x 372 km with a 92.1 minute period. This was an unusually high orbit. TASS reported that the work of the Donbass crew was coming to an end and that they were to begin mothballing the complex, words generally associated

The Mir crew are surrounded by the recovery team and journalists after the return to Earth on April 27. (Left to right) Dr. Valeri Polyakov, Aleksandr Volkov and Sergei Krikalev. *Novosti*

with closing down a Salyut station.

Then TASS revealed that the cosmonauts were to return home on April 27 and that Mir was to continue its flight in the unmanned mode!

This was a surprise to many western analysts. An American report of the Soviets shutting Mir down had emerged from attempts by a US TV crew to set up a radio link-up between Mir and Shuttle Mission 29 (STS-30) which was due for launch on April 28. The Soviets had been evasive in their acknowledgement of the Americans efforts and eventually admitted that Mir would probably be unmanned at the time of the American flight.

Deputy flight director Viktor Blagov confirmed the postponement of the Soyuz TM-8 flight of Viktorenko and Balandin and said that the "adjournment" was due to the delay in the launching of the two new modules. New training was needed, he said.

An American source, however, claimed that there was a different reason for the shutdown of Mir - a power supply problem.

Writing in *Aviation Week and Space Technology*, Craig Covault claimed that Western analysts eavesdropping on the air-to-ground conversations of Mir had heard discussions of electrical problems. He said that "serious electrical power problems" were afflicting the operation of the station. The major user of the electrical power was the life-support system.

A repair crew would need to be trained, Covault wrote, and the same team which had worked to salvage the Salyut 7 space station after it had suffered a complete loss of electrical power was put in charge of the new effort. Krikalev had been part of the team which had prepared documentation and training simulations for Dzhanibekov and Savinykh for their epic 1985 flight which rescued the stricken Salyut 7 station.

One analyst told this writer that batteries on Mir had been recharged from the solar panels only to discharge during operation. New batteries had been flown up on Progress 41 but the problem had continued.

Soviet officials denied the report but, according to writer Tim Furniss, Mir flight controller Valeri Ryumin confirmed that there was a problem with the batteries as described above.

Return of the Donbass Crew

The three-man crew on Mir spent much of their last days in space preparing the complex for a period - the Soviets said three months - without a crew. They conducted some more Earth observations and used the X-ray telescopes.

An inventory of the items accumulated over three years of operation of the station was made.

In preparation for their meeting with Earth's gravity, the men began regular sessions with the Chibis pressure suit which uses a vacuum to simulate the pull of Earth's gravity on their legs.

At 0146 on April 21, Progress 41 was undocked from the Kvant port and, after an autonomous flight of over five days, entered the atmosphere of Earth to a destructive reentry, at 1202 on April 25.

The crew, meanwhile had packed up their experimental results in the Soyuz TM-7 descent craft and conducted their final few experiments. Soyuz TM-7 undocked from the front axial port of Mir at 2328 on April 26.

Retrofire occurred at about 0200 April 27. The descent cabin touched down at 0259 in windy conditions due south of Tikenekty, some 140 km north-east of the town of Dzhezkazgan.

Rescue workers carried Krikalev in his seat to the medical tent after egress from the cabin. It emerged that he had injured his leg after knocking it against a control panel. Krikalev later reassured reporters that he was fine and that the injury was "nothing out of the ordinary".

Certainly, the three appeared in good spirits on TV coverage of the post-landing press conference.

Volkov said that the station had been prepared for three months of unmanned flight and that all spent systems had been replaced. Polyakov revealed that the men had put their signatures on each new device as their personal "guarantee of performance".

The cosmonauts were later flown to Star Town outside Moscow to recover. Thirty-six hours after landing the cosmonauts were reportedly able to move around quite freely.

The cosmonauts were given traditional awards. For Krikalev and Polyakov there was the Hero of the Soviet Union title as well as the Order of Lenin and the Gold Star. Volkov, already a Hero of the Soviet Union, was not given the title a second time but he was awarded the Order of the October Revolution.

Commercialisation of Mir

When the Soviet manned programme resumes in August it will be under the terms of a programme that must justify its existence under public scrutiny and tight economic conditions in the Soviet Union.

Accordingly, the programme is being increasingly commercialised. Two recent deals struck by Glavkosmos and foreign partners highlight the lengths that the Soviet programme is opening up for commercial gain.

Advertisement hoardings, already seen at Baikonur and the FCC during international flights, are to be painted onto the hull of Mir itself. Two panels 2 x 3 metres are being sold by the Swiss firm Punto and will be painted next August. Under the same agreement, firms could send one kilogramme of materials to the station and have a three minute video advertisement made by the cosmonauts. The cost of the package one million Swiss Francs.

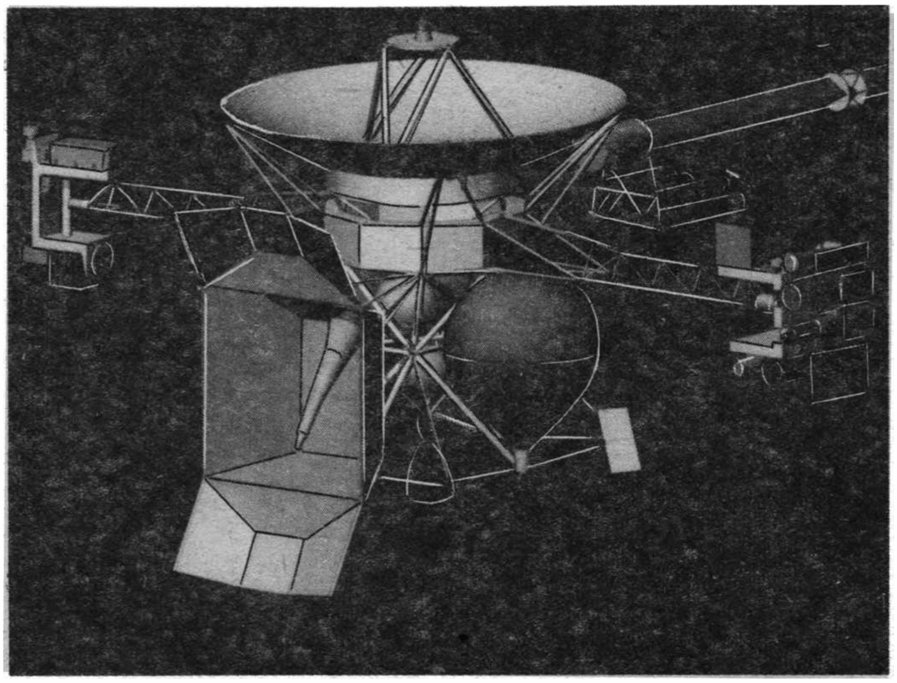
Glavkosmos recently signed a deal to fly a Japanese Journalist to Mir in 1991, where he, or she, will spend six days sending TV reports. The Tokyo-based TBS station is to provide the candidate . The thought of a Japanese newsreader sending down reports from orbit may be an interesting proposition but it had incensed many Soviet journalists who see it as a patriotic duty that the first journalist in space should be a Soviet.

A competition is underway to select a Soviet candidate for a flight to Mir but the question remains as to who will finance the deal. Glavkosmos sells opportunities for hard foreign currency. It is reported that the head of Soviet chemical industry offered hard currency to Glavkosmos head Aleksandr Dunayev for the flight. This move was severely criticised in sections of the press.

More scientific commercial agreements have been signed, or are under discussion with Austria, Great Britain, France and Malaysia.

Rendezvous with Comet Kopff

On August 14, 2000, after travelling for five years toward its goal, a sophisticated spacecraft carrying a dozen specialised scientific instruments orients itself to a precise attitude, makes a final check to ensure that all is ready, and then ignites its main rocket engine for a four-hour burn. With this manoeuvre, utilising over 1,800 kg of propellant, the spacecraft initiates a three-year rendezvous with the short-period comet Kopff, a meeting in which the spacecraft will study the comet in both its quiescent and active phases, will capture and analyse samples of its gases and dust, and will send a penetrator into its surface for *in situ* measurements.



The CRAF spacecraft with the penetrator in the foreground. *NASA/JPL*

By Sylvia Miller and Sima Lisman
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

The Comet Rendezvous Asteroid Flyby, or CRAF, mission is planned by NASA for a joint new start in fiscal year 1990 along with Cassini, a NASA/ESA Saturn orbiter with a probe to be released into the atmosphere of Saturn's large satellite Titan. These are the first two missions of the Mariner Mark II programme, so named after the new spacecraft being designed at the Jet Propulsion Laboratory for such challenging primitive-body and outer-planet missions. Launching in 1995 and 1996, respectively, these two mission will provide new perspectives on our origins: the formation and evolution of the solar system and the prebiotic evolution of molecules which may have led eventually to the origin of life.

In September 1988, NASA included in its fiscal year 1990 request to the Office of Management and Budget a new start proposal for the CRAF/Cassini initiative. In November, ESA officially gave its support to Cassini by approving funding for the probe, now called Huygens, which will be carried by the American-built Saturn orbiter. Back in Washington, the Office of Management and Budget approved the programme and, in January of this year, CRAF/Cassini became a line item in the budget submitted to Congress.

Earlier, the Ministry for Research and Technology (BMFT) of the Federal Republic of Germany agreed to supply the propulsion module subsystem for the CRAF spacecraft, an arrangement similar to that of Galileo, Cassini's sister mission to the Jovian system which is scheduled to be launched in October 1989. The CRAF science payload was selected in 1986 and included a West German instrument plus German support for a second instrument. In October 1989, Announcements of Opportunity will be issued simultaneously in the United States and Europe for the scientific payloads of both the Cassini orbiter and probe. With a fiscal year 1990 new start, the CRAF/Cassini programme will be ready to begin the development of the spacecraft and detailed mission plans leading to the next phase in the study of the primitive bodies and the outer solar system.

The Authors

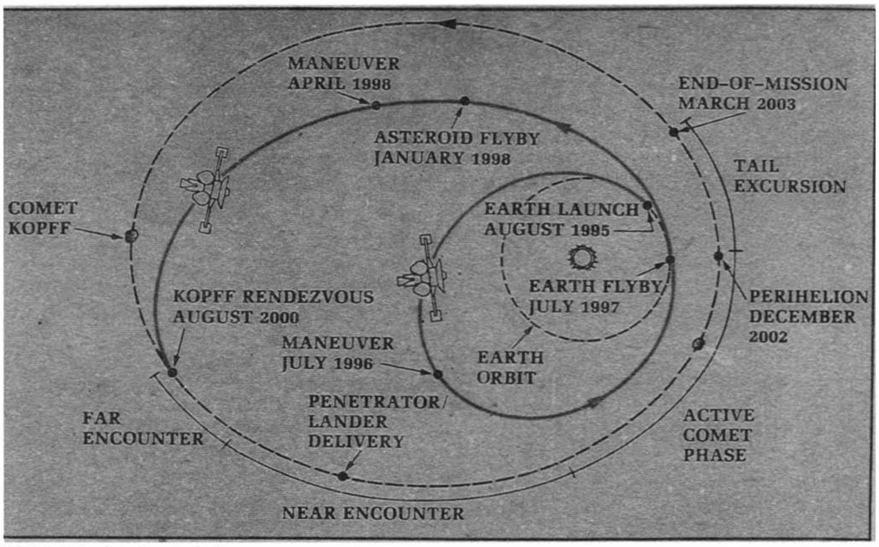
Sylvia Miller (left) has held the position of mission design engineer for CRAF since 1983. During her twenty years at JPL, she also worked on the Infrared Astronomical Satellite, Voyager, Seasat, and various advanced studies. She received her B.A. degree in mathematics from Douglass College and her M.S. degree in systems engineering from West Coast University.

Sima Lisman (right) has worked on the Mariner Mark II project in the spacecraft systems engineering section at JPL for over two years. She received her B.S. degree in electrical engineering from California State Polytechnic University and is pursuing an M.S. degree in electrical engineering at the University of Southern California.

Primitive Bodies

For understanding our origins, comets and asteroids provide important records of early solar system formation. These small bodies have suffered less of the heating and other modifications that have affected the inner planets and larger bodies. Comets are particularly interesting because they are probably icy remnants of the time of the outer planets' accretion, having been flung out into the Oort cloud halfway to the nearest stars or, alternatively, been stored in the region of the solar system just beyond the orbit of Neptune. Hence, the volatile material preserved in comets is probably closerst to that of the primordial solar nebula than that of any current body in the solar system.

Asteroids are thought to be similar to the planetesimals commonly believed to have formed the terrestrial planets and cores of the giant outer planets. The main belt of asteroids, a relatively stable region between the orbits of Mars and Jupiter, contains the boundary between the water-condensing region and the water-vapour region of the protosolar nebula. This difference is visible in the strata of spectral types observed among the aster-



CRAF's interplanetary trajectory.

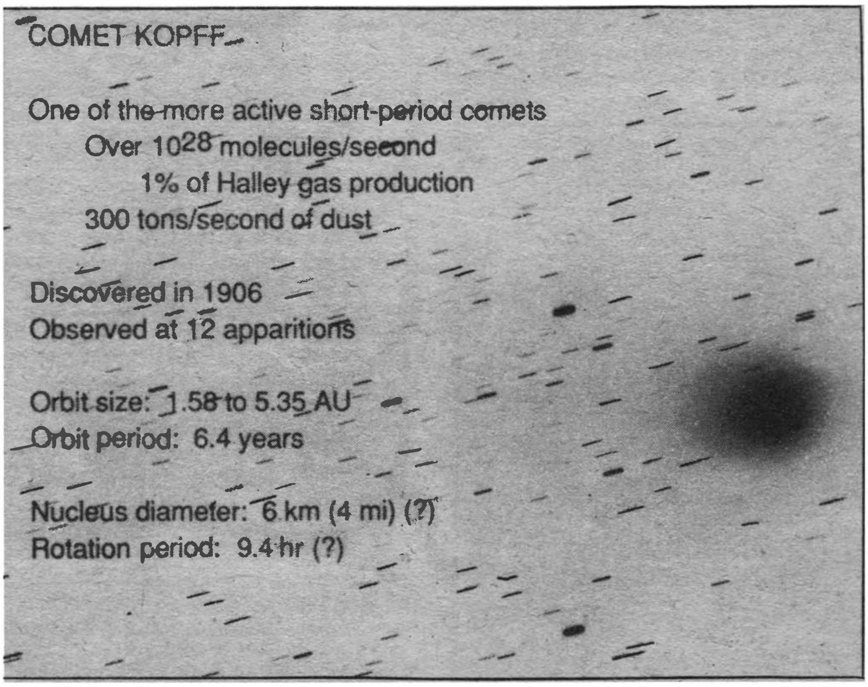
oids across the belt. The apparent diversity of the asteroids ranging from differentiated, rocky objects to bodies rich in volatiles and hydrocarbons, tells us that we can learn much about the formation of bodies in the solar system by visiting a wide variety of these asteroids.

Not only will CRAF provide us with the opportunity to analyse primordial materials, but we will be able to observe physical processes that may be similar to those that occurred in the solar nebula. By travelling with a comet for half of its orbital cycle, CRAF will observe the processes that take place in the comet as it transforms from a relatively quiescent dirty ice ball at 4 and 5 Astronomical Units (AU) from the Sun to its active state near perihelion, when it is spewing forth dust and gas into its coma and tail. Not only are the processes within the comet of interest, but also the interactions between the comet's coma and the supersonic solar wind plasma are intriguing.

Comets and asteroids may also provide clues to prebiotic molecular evolution in the solar system. Recent research suggests that the early atmosphere on Earth may have been inhospitable to the development of the complex molecules necessary for the evolution of life, that these molecules may instead have been brought to Earth from the outer solar system by comets and asteroids.

The primary target selected for CRAF is P/Kopff. Discovered by August Adalbert Kopff in 1906 at Heidelberg Observatory, Comet Kopff has been observed during 12 perihelion passages. It was recovered again in February 1988, almost 4 AU from the Sun, with the next perihelion to occur on January 20, 1990. With its aphelion distance at 5.4 AU from the Sun, its perihelion distance at 1.6 AU, and an inclination of 5 degrees with respect to the ecliptic plane, its orbit is typical of short-period comets. It is one of the most active short-period comets in the solar system, however, and therefore and excellent target for the intensive studies planned for this rendezvous mission.

Comet Kopff with relevant information. The image was taken through a 4-metre telescope at Kitt Peak Observatory, Arizona, on August 13, 1983. *National Optical Astronomy Observatories*



En route to Comet Kopff, the CRAF spacecraft will fly by the asteroid 449 Hamburga. Named for the city of Hamburg, Germany, this main belt asteroid has a semimajor axis of 2.6 AU. It was discovered in 1899 by M. Wolf and A. Schwassman, also at Heidelberg. Hamburga is of spectral type C, that is, its surface is thought to be composed of material similar to the carbonaceous chondrite meteorites. Type C asteroids are among the more primitive types of asteroids, with high volatile contents. With a substantial diameter of almost 90 km, Hamburga will provide a nice complement to the asteroids of the Galileo and Cassini missions.

Advantages of a Rendezvous Mission

The exciting fast flybys of Comets Giacobini Zinner and Halley in 1985 and 1986, respectively, offered tantalising glimpses and data of the first encounters with this class of body. They raised many important questions, however, and emphasized the need for a lengthy stay with a comet. A rendezvous mission, wherein the spacecraft matches orbits with the comet, allows the comet to be observed in both its quiescent and active phases, including the important transition between the two. The spacecraft can, therefore, make measurements as a function of activity level and position with respect to the nucleus and the Sun. Detailed mapping of the surface is possible from close proximity for 100% coverage with a variety of lighting conditions. Long integration times are possible and a penetrator can be implanted in the nucleus for *in situ* measurements. Furthermore, low relative velocities allow dust particles to be captured intact for physical and chemical analyses. Finally, a long-duration visit means that there is time to adapt the mission plans to new, important information as the mission progresses.

Mission Plan

CRAF is launched from the Kennedy Space Center in Florida by an expendable Titan IV/Centaur launch vehicle on August 22, 1995. The mass of the spacecraft, propellant, and launch-vehicle adaptor is 5270 kg. The initial trajectory takes the spacecraft out past the orbit of Mars. There, a sizable manoeuvre is performed, lowering the perihelion of the orbit and creating the right geometry for a subsequent flyby of Earth. The resulting gravity assist from Earth, slightly less than two years after launch, increases the heliocentric speed of the spacecraft from 34 to 38 km/s and sends it on its way to rendezvous with Comet Kopff near the orbit of Jupiter. Using this Delta Velocity Earth Gravity Assist trajectory, the spacecraft can reach the outer solar system while requiring only a low, inner solar system launch energy.

During this cruise phase, science data gathering is limited primarily to the particles and fields experiments. Other instruments, such as the remote sensing instruments, are

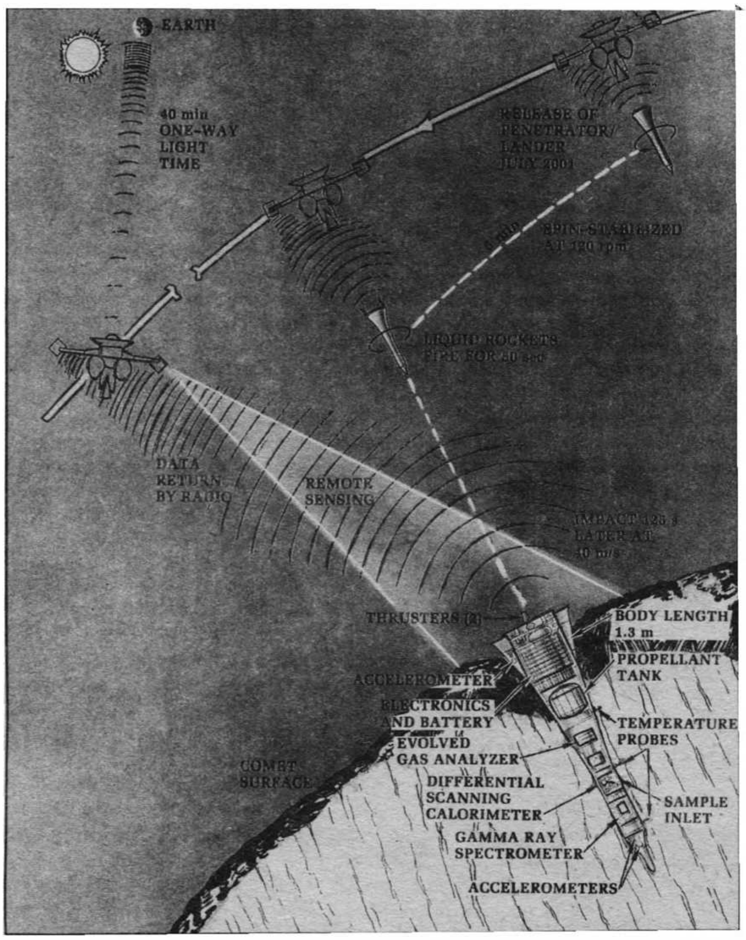
turned on at intervals for calibrations and occasional use. One 8-hour station pass per week with the Deep Space Network is planned for communications.

About six months after the Earth flyby, the spacecraft flies past 449 Hamburga with a relative speed of 17 km/s at closest approach. By targeting to within 80 radii (3,540 km), the mass of the asteroid may be determined with an accuracy of better than 10%. This mass determination, along with an estimate of the volume from images taken by the wide- and narrow-angle cameras, allows what may be the first estimate of the bulk density of an asteroid, a key parameter for bounding asteroid formation theories. All of the remote-sensing instruments are operating during the flyby, imaging the object and making compositional and thermal measurements, and the dust detector measures the number and mass of small particles encountered near the asteroid. The gas and plasma instruments search for any residual comet-like activity and any evidence of an intrinsic magnetic field.

In April, 1998, three months after the asteroid flyby, the spacecraft performs a plane-change manoeuvre for its final targeting to Comet Kopff.

During the late 1990s, observations using Earth-based telescopes refine the ephemeris of the comet. By approaching it from the Sun side, the spacecraft is expected to be able to find the comet with the onboard narrow-angle camera about a month before the planned rendezvous in August 2000. After acquisition is confirmed, the approach strategy and parameters for the critical rendezvous burn are finalised. This large burn takes place about 200,000 km from the comet's orbit, a safe distance away from the dust and debris that is expected to be orbiting the Sun in that vicinity. This debris could be hazardous to the spacecraft at the fast approach speed of over 2 km/s. The burn, which may actually be broken into two parts, leaves the spacecraft in an orbit around the Sun nearly matching that of the comet, with a residual approach speed of only 45 m/s. During this and subsequent phases, the spacecraft uses a minimum of nine station passes per week to communicate with Earth.

During the approach over the next four and a half months, remote-sensing instruments send back visual and infrared images which provide an initial characterisation of the comet nucleus: its shape, size, rotation rate, pole orientation, and state of activity. It is expected that the nucleus will by irregularly shaped, like the nucleus of Comet Halley, with an average diameter of about 8 km. Its pole may be nutating and precessing. At a distance of 2,500 km, the relative speed is reduced to 2.5 m/s for the final approach. Starting with this phase, the dust counter and neutral gas and ion mass spectrometer operate continuously, broadcasting the instantaneous dust flux and gas pressure, respectively, to the rest of the spacecraft. Based on these data, instruments may choose to automatically close their dust covers for protection. Dust analysers passively collect dust particles for future analysis. Initial estimates of the mass of the nucleus are obtained during this phase, particularly during a series of successively closer flybys, with a final



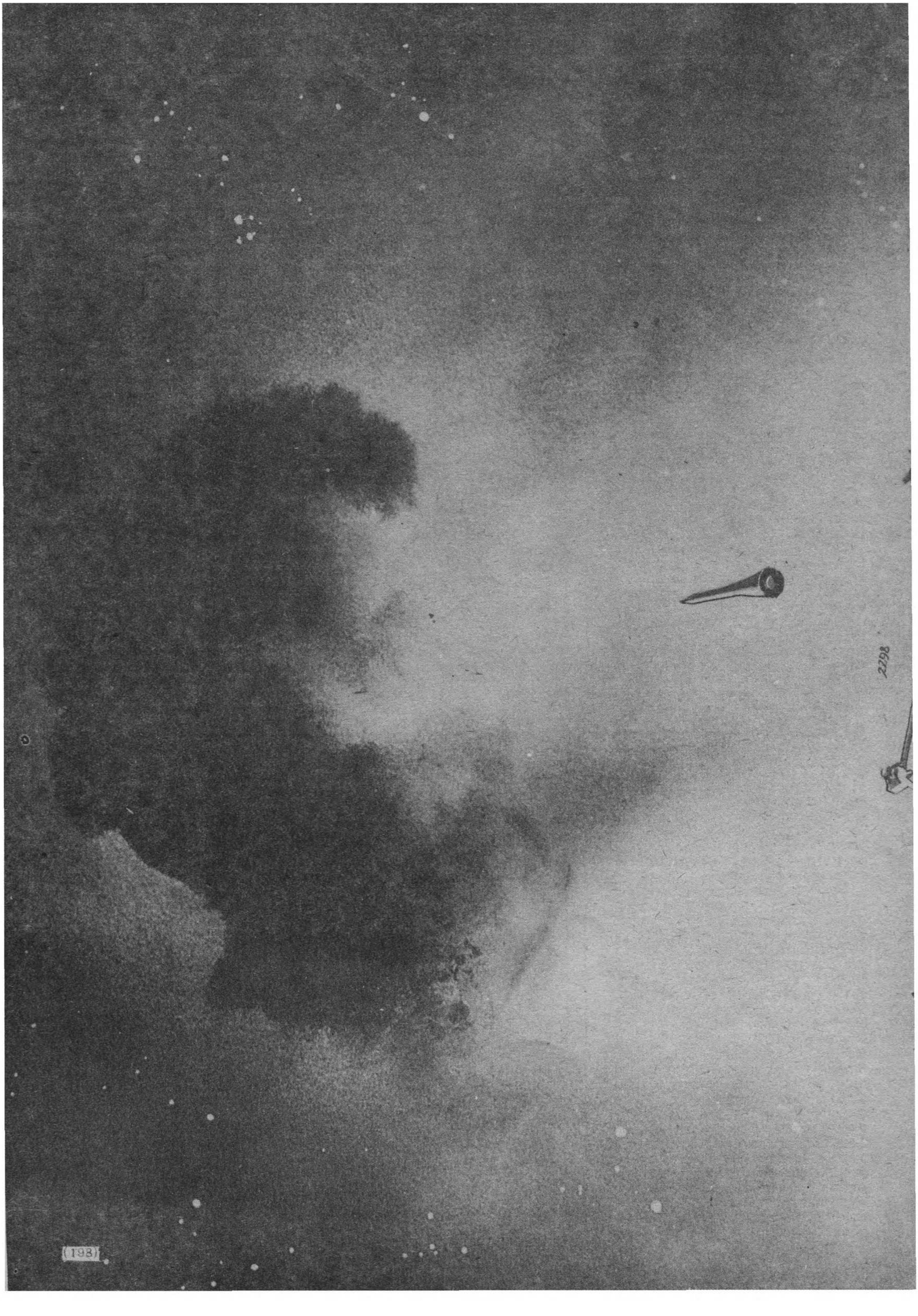
Penetrator/lander mission.

approach to within 50 or 100 km. This phase ends with a manoeuvre which inserts the spacecraft into orbit around the nucleus for a 500-day near-encounter phase.

The initial orbits are planned to be circular with a period of ten days. In this gravitationally weak environment, a ten-day period corresponds to a radius of perhaps 60 km; the exact distance will depend upon the mass of the nucleus. The visual and infrared remote-sensing instruments send back to Earth detailed information about the surface composition, morphology, and temperature of the comet. Images from the narrow-angle camera have a resolution of better than one meter. Within two orbital periods, radio science refines the nucleus mass estimate to an accuracy of a fraction of one per cent. As with

CRAF SCIENCE INVESTIGATIONS

ACRONYM	INVESTIGATION	PRINCIPAL INVESTIGATOR/ TEAM LEADER	INSTITUTION
ISS	Imaging (Facility)	Dr Joseph Veverka	Cornell University
VIMS	Visual/infrared mapping spectrometer (Facility)	Dr Thomas B McCord	University of Hawaii
TIREX	Thermal infrared radiometer experiment	Dr Francisco P J Valero	NASA Ames Research Center
PEN	Penetrator	Dr William V Boynton	University of Arizona
COMA	Cometary matter analyzer	Dr Jochen Kissel	Max-Planck-Institut für Kernphysik
CIDEX	Comet ice/dust experiment	Dr Glenn C Carle	NASA Ames Research Center
SEMPA	Scanning electron microscope and particle analyzer	Dr Arden L Albee	California Institute of Technology
CODEM	Comet dust environment monitor	Dr W Merle Alexander	Baylor University
NGIMS	Neutral gas and ion mass spectrometer	Dr Hasso B Niemann	NASA Goddard Space Flight Center
CRIMS	Comet retarding ion mass spectrometer	Dr Thomas E Moore	NASA Marshall Space Flight Center
SPICE	Suprathermal plasma investigation of cometary environments	Dr James L Burch	Southwest Research Institute
MAG	Magnetometer	Dr Bruce Tsurutani	Jet Propulsion Laboratory
CREWE	Coordinated radio, electrons, and wave experiment	Dr Jack D Scudder	NASA Goddard Space Flight Center
RSS	Radio science (Facility)	Dr Donald K Yeomans	Jet Propulsion Laboratory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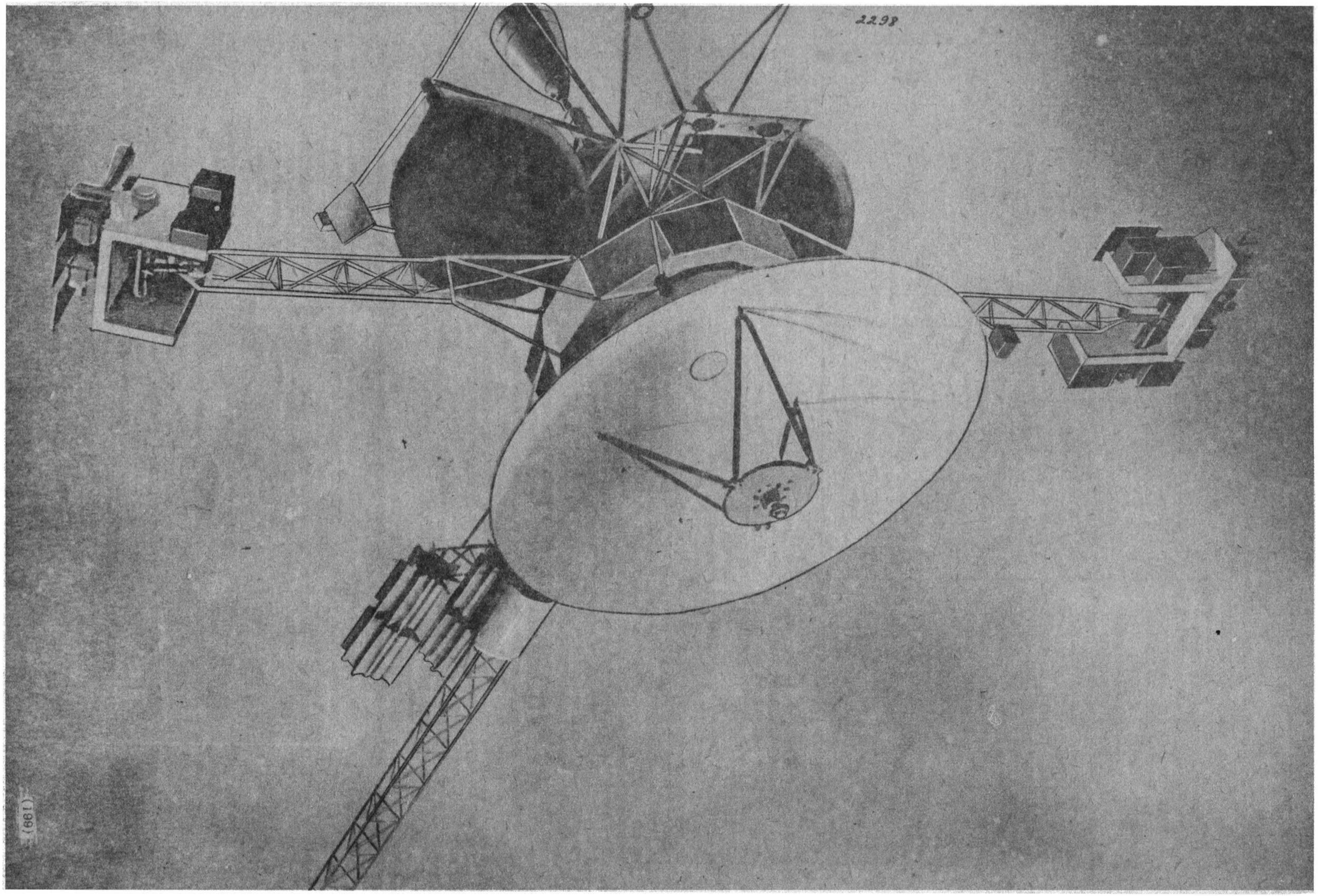

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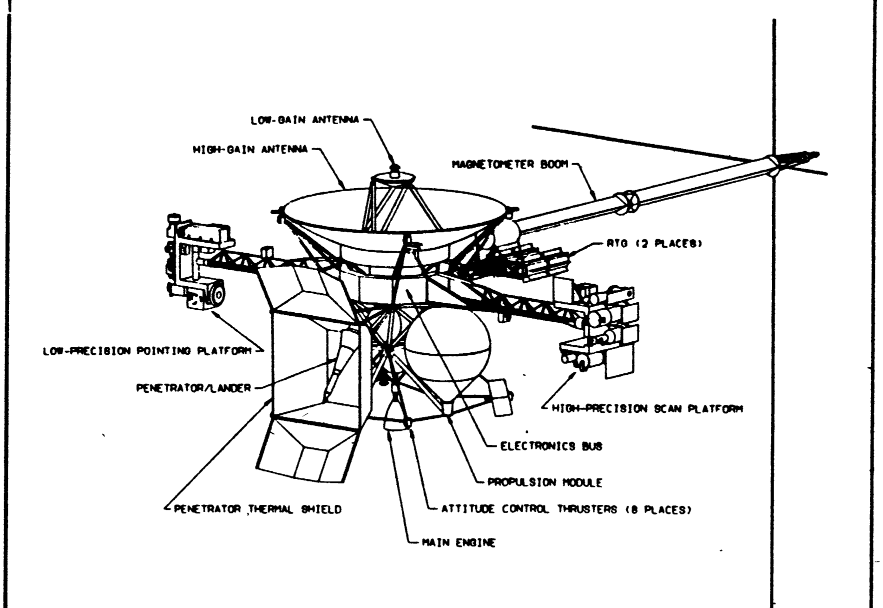
the asteroid, the mass estimate, together with a good estimate of the volume, produce the first accurate estimate of the bulk density of a comet. These data allow us to create and validate theories of the original accretion of the nucleus and of the processes that have occurred since then.

One of the results of this phase is the selection of a site for deploying the penetrator. Thought to be conglomerates of frozen gases and less volatile, organic and silicateous dust, comets may have crusts of dark, organic material. An area on the nucleus is sought where this crust is relatively thin (or absent) so that the ice below can be reached by the penetrator. A rather smooth surface is also desirable for a high probability of successful implantation. Candidate targets are selected and studied in more detail. With the site selected about a year after rendezvous, the spacecraft manoeuvres into the proper orbit for delivery. About 12 km above the site the penetrator spins up to 120 rpm, is released from the spacecraft, and, after a five-minute coast, fires two small liquid rocket engines for 50 seconds. It impacts the surface about 125 seconds later at about 40 m/s. About 1.3 m in length, the penetrator is expected to implant itself about a metre into the surface. It carries accelerometers for measuring the strength of the surface material, temperature probes for measuring thermal characteristics, a gamma-ray spectrometer to identify the elemental composition of the surrounding material, and instruments for onboard analysis of a small ice sample. The penetrator sends its data to the spacecraft at regular intervals during the next nine days for relay to Earth.

After the penetrator phase, the spacecraft continues to study the surface of the nucleus in detail with orbits of various sizes, inclinations, and orientations. As the comet and spacecraft approach the Sun, onboard instruments search for s ns of increased activity on the comet: bursts of gas and dust from weak spots in the crust, the formation of the coma, and the initial development of an ion tail. After the onset of activity, changes are expected to be visible on an hourly basis, providing an exciting movie-like scenario of the world of Comet Kopff.

At 2.5 AU from the Sun, about 200 days before the comet's perihelion, the activity is expected to have increased enough so that the spacecraft backs away from the nucleus to keep from accumulating too much dust and also to explore this interesting region of activity. No longer in orbit, the spacecraft executes about 20 slow flybys of the nucleus, approaching as close as perhaps 50 km for dust collection, but spending most of the time at distances of several hundred to several thousand kilometres. The spacecraft appears to trace out petals of a daisy around the nucleus in this exploration of the coma. While some instruments analyse dust particles for their elemental, chemical, and microscopic properties, others analyse sampled gases for their composition, velocity, and temperature. A set of plasma instruments studies the inter-

Centre Page: An artist's impression of the CRAF space craft and with its penetrator probe hurtling towards Comet Kopff.
NASA/JPL



CRAF spacecraft configuration, isometric view.

actions of the gas and dust with the solar wind.

After perihelion, on December 12, 2002, the spacecraft begins an excursion into the comet's now fully developed ion tail. Instruments continue to study the interactions of the comet with the solar wind in an effort to understand the reasons for the constantly changing shapes of comet tails, the acceleration of energetic particles, and other plasma phenomena. Taking 90 days for the round trip, the spacecraft reaches a distance of 50,000 km from the nucleus before returning.

During the last ten days of the mission, as the comet's activity wanes, the spacecraft again flies by the nucleus for a quick assessment of changes that have occurred as a result of the perihelion passage. The nominal mission ends on March 31, 2003. If resources are available, an extended mission would be desirable, allowing a more thorough post-perihelion examination and a study of the comet's cooling-down processes for comparison to the heating-up processes already observed.

Spacecraft

As stated earlier, the CRAF spacecraft is the first of the Mariner Mark II series. These spacecraft are equipped to transmit large amounts of data to Earth over vast distances, generate electrical power far from the Sun and provide highly accurate pointing for remote-sensing instrument and delivery of penetrators and probes. By Mariner Mark II design philosophy, the spacecraft are modular and can easily be adapted to different missions. Where requirements of various missions differ, the design of common spacecraft elements is driven by the most demanding mission. The cost of over designing for the missions with less stringent requirements is more than compensated for by savings in the design, construction, test, and operation of identical components. Use of proven designs and even inherited hardware is maximised and new technology is used only when it is cost effective and a viable backup is available. Functional and block redundancy in engineering subsystems ensures spacecraft recovery from single-point failures. Standard data interfaces and telemetry formats are used to simplify the design and minimise the impact payload changes. Large design margins in mass and performance are maintained to aid in cost control.

Primary CRAF spacecraft elements include a high-gain antenna, two low-gain antennas, a ten-bay electronics bus, two radioisotope thermoelectric generators (RTG), two independently articulable instrument platforms, a fixed magnetometer boom, a propulsion module, and a launch vehicle adapter. During launch, the instrument platforms and the RTG boom are folded and latched to the adapter and the magnetometer boom is stowed in its canister. After launch and prior to separation from the Centaur upper stage, the instrument platform and RTG booms are deployed. The spacecraft is then separated from the adaptor using pyrotechnic devices and the magnetometer boom is extended.

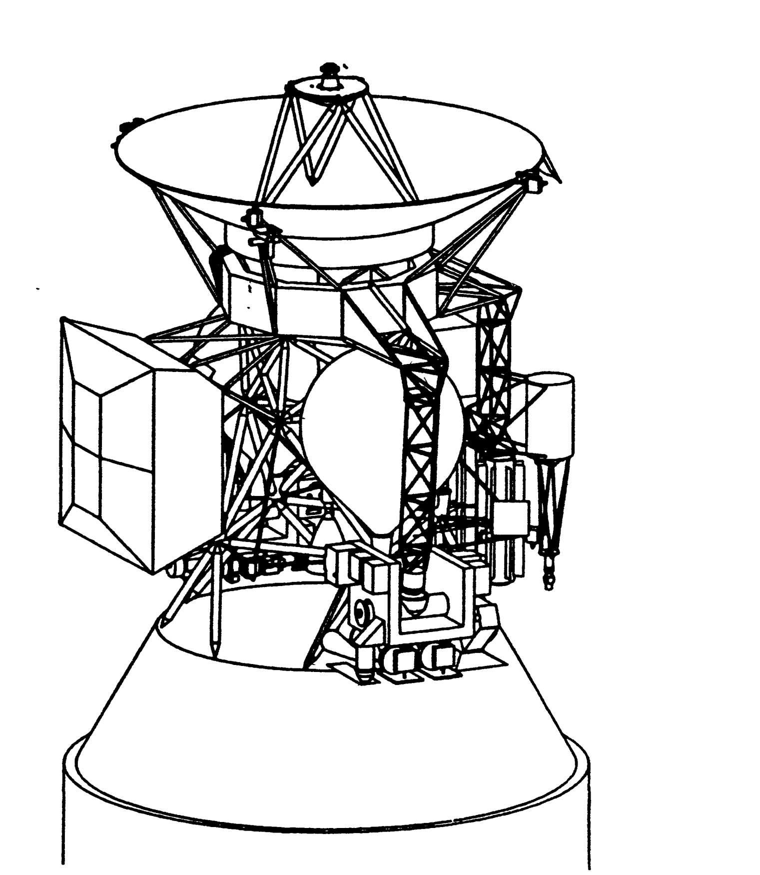
The structure subsystem integrates all spacecraft elements into the flight spacecraft system. Its main element is a ten-bay toroidal bus which houses most of the electronics and provides structural support for the spacecraft. The high-gain antenna is located on top of the bus. Two science booms are placed opposite each other to support the two instrument platforms, the high-precision scan platform and the low-precision pointing platform. These booms provide vantage points, giving the science instruments relatively clear fields of view. The magnetometer boom canister and the two RTGs are attached to a third boom. This boom lowers the RTG radiation at the spacecraft and reduces spacecraft magnetic interferences at the magnetometer. The propulsion module subsystem is mated with the bottom of the bus.

The propulsion module subsystem provides thrust for the spacecraft. Messerschmitt-Belkow-Blohm (MBB) has agreed to supply

this subsystem under contract to the German Aerospace Research Establishment (DLR) of the Federal Republic of Germany. Two large, conispherical, bipropellant tanks hold up to a total of 3,450 kg of monomethylhydrazine fuel and nitrogen tetroxide oxidizer for main rocket engine use. The main engine, used for large manoeuvres, is based on the 400-newton (90 Lbf) Galileo engine. A pressurant tank is located in the centre of the propulsion module. Reaction control system thrusters are 0.2-newton, monopropellant thrusters and are used in couples. They utilise hydrazine (N_2H_4) to provide thrust for attitude control and small manoeuvres. Four thruster clusters are placed around the perimeter of the high-gain antenna and four other clusters are placed at the bottom of the propulsion module.

The attitude and articulation control subsystem maintains three-axis control of the spacecraft and articulates the instrument platforms. The star tracker is a redundant Advanced Star and Target Reference Optical Sensor (ASTROS II) unit. It is an improved version of ASTROS I, which was to be flown on Shuttle flights to observe Comet Halley. The inertial reference units (four units in one package) are new fibre-optic rotation sensors (FORS) which have no moving parts and use light travelling through a long fibre-optic cable to determine spacecraft angular rates. Both the FORS and the star tracker are placed on the high-precision scan platform to provide two-axis, high-accuracy pointing for the remote-sensing instruments. This platform has a pointing control accuracy in inertial space of 2.0 milliradians, with 1.0 milliradian pointing knowledge, and a maximum slew rate of 17.5 milliradians per second. Its motion is momentum compensated by a reaction wheel system mounted on the propulsion module. The reaction wheels are used for nominal attitude control (including high-gain antenna pointing) of the spacecraft after comet rendezvous, with the small thrusters being fired periodically to off-load the accumulated angular momentum of the wheels. The low-precision pointing platform also provides two-axis pointing articulation. Its pointing control accuracy and knowledge are both 17.5 milliradians. Both platforms can be articulated through a wide range of angles to provide better instrument pointing without rotating the spacecraft bus. A resident microprocessor in the attitude control electronics and another microprocessor in the star tracker provide the necessary computations for the attitude control functions. Two redundant Adcole Sun sensors look along the direction of the high-gain antenna and residual Viking Orbiter gimbal actuators provide pointing control for the 400-newton engine during manoeuvres.

The radio frequency and antenna subsystems provide all the communications to and from Earth. Using only X-band frequencies (8.4 GHz), this telecommunication system includes a 3.7 metre, high-gain antenna (based on the Voyager design), two low-gain antennas, a new command detector unit (also being used by Mars Observer), a new NASA X-band transponder, a telemetry modulation unit, and a new 5.6 watt, solid-state power amplifier. The high-gain antenna size is determined by the distance between Saturn and Earth for the Cassini mission; a smaller antenna would be sufficient for the CRAF mission. The downlink data rates vary between 13 and 115 kilobits per second depending on the distance between the spacecraft and the Earth and the particular ground station being used. A low-gain antenna is used in the event of an emergency and during main engine burns, during which time the high-gain antenna is not able to point toward Earth. It is also used when the spacecraft is near Earth.



CRAF spacecraft configuration for launch by Titan IV/Centaur.

The power and pyro subsystem regulates and distributes all of the power needed by the spacecraft. This 30-volt DC power is supplied by two RTGs capable of providing 557 watts at the beginning of the mission. Two batteries, of 135 watt-hour capacity each, provide energy storage and allow intermittent engineering and scientific loads above the RTG capability. They are connected to the power bus through bidirectional converters.

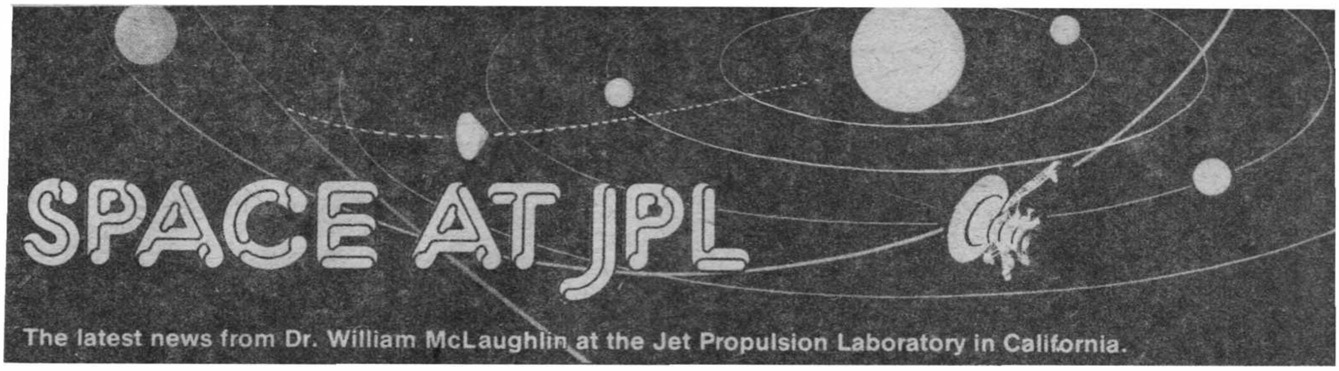
The command and data subsystem receives commands from Earth through the radio frequency subsystem and distributes those commands along with certain engineering data to the appropriate subsystems. It also collects telemetry packets from the subsystems either for transmission to Earth or for temporary storage. System-level fault detection and correction algorithms are resident in the command and data subsystem memory to ensure spacecraft integrity. The high-level programming language C is used to keep software development and maintenance costs low.

The data storage subsystem provides storage mediums for on-board data during times which downlink telemetry is not available or when the amount of onboard data exceeds the downlink capabilities. This subsystem uses a spare Galileo digital tape recorder with 0.9 gigabits of capacity. Four record rates up to 403.2 kbps and four playback rates up to 100.8 kbps are available. In addition, redundant 35-megabit, solid-state buffer memories provide data rate matching between the subsystems and the tape recorder, as well as between the tape recorder and the downlink. The buffers are also used as a backup to the tape recorder for critical data such as optical navigation frames and the penetrator relay data.

In addition to the above subsystems, thermal control of the spacecraft is provided by traditional methods such as electrical heaters, radioisotope heater units, multilayer insulated blankets, louvres, and radiators. Mechanical devices deploy and hold in position the instrument platform booms, the RTG boom, and the magnetometer boom.

Summary

The CRAF mission offers an opportunity to explore the mysteries of a comet during an extended rendezvous; it is the next logical step in the exploration of these remnants from the formation of the solar system. CRAF will also contribute to the reconnaissance of the other major class of primitive bodies, the asteroids. The vehicle to be used will establish a new, modular design for spacecraft which can carry out sophisticated missions in the outer solar system.



Neptune Encounter Begins

On June 5, at 6 hr 42 min 23 sec UTC (in spacecraft event time) at a range of somewhat less than 120 million km from Neptune, Voyager 2 will enter its "Observatory Phase" signalling the start of the planetary encounter which will last until October 2, with closest approach to the planet occurring at 04:00 UTC on August 25. This will be the fourth and last planetary encounter for the spacecraft that was launched on August 20, 1977 and will complete the Grand Tour of the giants Jupiter, Saturn, Uranus and Neptune.

Already, images of Neptune from Voyager 2 and from Earth-based telescopes indicate that the atmosphere of the planet displays features, unlike the bland face of Uranus. Previous flybys of Jupiter and Saturn by Voyagers 1 and 2 (Saturn was the last planetary encounter for Voyager 1; it is now in cruise toward interstellar space) determined that they have internal heat sources, which are a factor in their noticeable atmospheric dynamics. No internally generated heat was measured at Uranus. Hence, it is reasonable to anticipate that Neptune may possess some interesting internal processes to accompany its visual attractions.

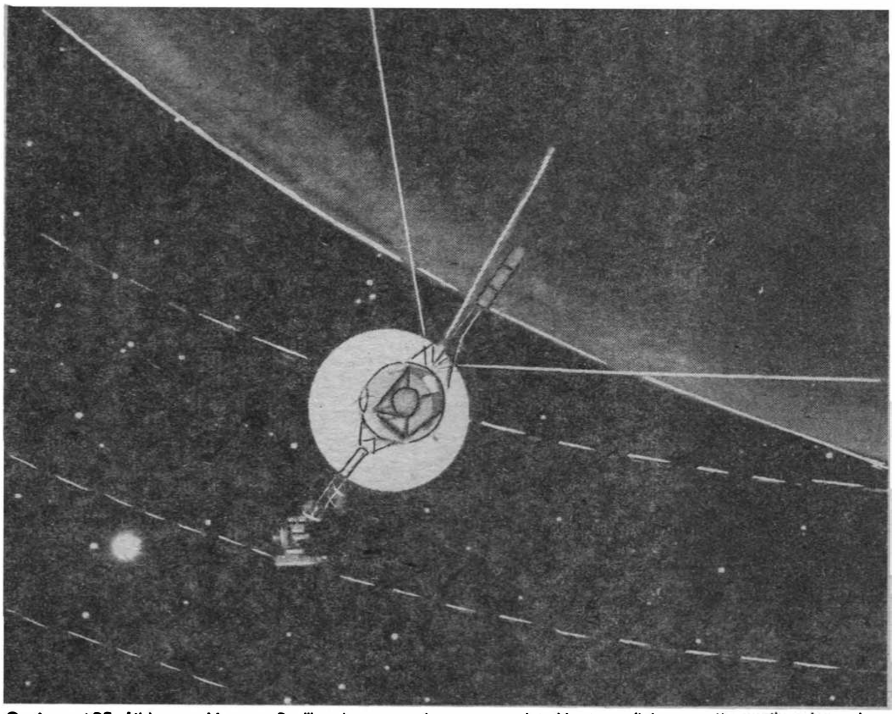
The anatomy of the encounter consists of four phases: Observatory (as mentioned above), Far Encounter,Near Encounter, and Post Encounter.

The Observatory Phase extends to August 6. It features synoptic views of the Neptunian system - the imaging system will be used to produce movies of atmospheric dynamics and the ultraviolet spectrometer will be scanned across the system - fields and particles measurements, instrument calibrations, and a trajectory correction manoeuvre.

Far Encounter begins at approximately 27 million km from Neptune and lasts from August 6 to August 24. The increasing apparent size of the planet permits atmospheric heat-balance studies and higher-resolution images (including views of the satellites Triton and Nereid and the possible system of rings) along with more movies. Two trajectory correction manoeuvres are scheduled for this phase.

The centrepiece of the flyby is the Near Encounter Phase, August 24 to August 29. During this time high-resolution remote sensing, probing of Neptune's and Triton's atmospheres with electromagnetic waves, and sampling of the fields-and-particles phenomena inside the magnetosphere will supply the highest-value science of the mission. Near Encounter observations were described in some detail in the December 1988 edition of "Space at JPL".

The Post Encounter Phase extends until October 2, when Voyager 2 will be about 56 million km beyond Neptune. It represents a last chance to gather data with the complement of 11 scientific experiments before the spacecraft sweeps well beyond the most distant planet. (In the December piece I erred in saying that Neptune would retain most-distant status until early in the next century. Roy D. North of Colorado Springs, Colorado, informed me that eccentrically orbiting Pluto will regain its distinction of being the most distant known planet on February 9, 1999.)



On August 25 of this year, Voyager 2 will make a very close approach to Neptune, flying over the north-polar region of the planet. At this distance the Sun shines with a brightness of only about one-tenth of a per cent of its apparent radiance at Earth. *NASA/JPL*

Norman R. Haynes is the project manager for Voyager. Prior to this assignment he managed the Systems Division at JPL and has held a variety of key positions at the Laboratory, including Mission Analysis and Engineering Manager for the Mariner 9 Mars-orbiting mission, launched in 1971. We discussed the plans that the Voyager Project has formulated to maximise the probability of successfully completing its survey of the Neptunian system, and the results of our conversation are reported below.

Last August the project compiled a list of possible events that could pose threats to the mission and ranked them in priority order, assigning a relative risk category to each (high, medium or low) and identifying the actions being taken to protect against loss. Nineteen items appeared on the list, and although Haynes said that subsequent knowledge would probably re-order the risk rankings if a recompilation were made, it is instructive to review the evaluation.

The first high-risk potential problem on the list would materialise if Voyager 2 lost its one remaining radio receiver and was therefore unable to receive commands from Earth. This concern is an old one, the primary radio receiver having failed in 1978, prior to the encounter with Jupiter. Partial protection against this contingency is provided through the means of a "Backup Mission Load" (BML): a sequence of commands carried on board the spacecraft and automatically activated in case of a receiver failure. This BML would autonomously conduct a reduced survey of the Neptunian system and send the data back to Earth.

The second of the two items in the category of high risk (again, relative to the other items on the list, not "high" in an absolute sense) would occur if one of the two Flight Data Subsystem (FDS) Computers were to fail. The Voyager spacecraft has two of these solid-state devices and one failed on Voyager 1 several years ago. Failures of isolated groups of memory cells of the FDS have been experienced on Voyager 2 over the years. The FDS is used to control the state of the instruments and to format data prior to transmission to Earth. Protection against this type of failure is provided by alternative software which could be loaded into the remaining FDS to accomplish the essential functions of this subsystem.

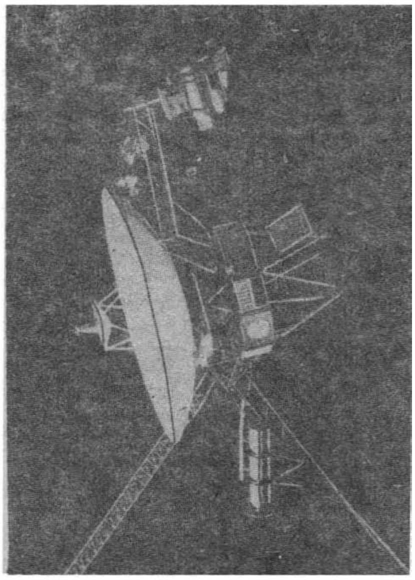
Entering the category of medium risk, we move from the domain of potential flight-hardware anomalies to activities conducted by people on Earth. Problems three and four on the

list focus on concern over the high activity required by the flight team in the time period around closest approach. The primary purpose of such activity is to incorporate the latest information about the Neptunian system and the spacecraft's ephemeris into the command loads for the spacecraft. Complex tasks, having to be done quickly, can breed errors. The response of the project has been to conduct a comprehensive series of test and training exercises, the most intensive in Voyager's history.

Skipping down the list to problem seven (medium risk), we find provisions made to cope with an earthquake or other natural disaster if it should knock out command and control facilities at JPL. A copy of the command load covering closest approach will be held at one of the tracking stations of the Deep Space Network and would be uplinked to the spacecraft at the appropriate time.

Environmental problems at Neptune, related to unexpected ring material, intensive flux of high-energy charged particles, or drag from a hyper-extended planetary atmosphere appear at the twelfth position on the list (low risk) and are treated by a variety of prophylactic measures. For example, a late trajectory-correction manoeuvre can adjust to a small degree the relation of the spacecraft's trajectory to regions of observed ring material. Software has been installed onboard the spacecraft to protect against the most deleterious effect from high-energy charged particles: introduction of timing offsets between Voyager's various onboard computers. In case the atmosphere of Neptune is more extended than current models predict for this north-polar flyby a few thousand km above the cloudtops, the control authority of the spacecraft's attitude-control system will be strengthened (to deal with torques which would be introduced by atmospheric drag). This strengthening will be accomplished by commanding the spacecraft's attitude-control thrusters, which periodically emit bursts of hydrazine to keep the spacecraft in equilibrium about its nominal attitude (orientation), to fire more than the usual amount of hydrazine propellant through their nozzles, per burst.

The mission has been carefully devised to obtain important scientific information from this distant outpost of the Solar System, and bulwarks against many of the slaps of chance are in place. Haynes summarised the status of the Voyager Project as the encounter begins: "we're ready".



The 3.7 m high-gain antenna dominates the visual aspect of the 815 kg Voyager spacecraft. *NASA/JPL*

Mountain Waves and Polar Ozone

Bruce Gary was staring out the window of an airliner on the way to Mexico in 1977 and, seeing some nearby cirrus clouds, speculated how useful it would be to know temperature profiles in that region. With knowledge of temperatures throughout a region of the atmosphere, Gary reasoned, dynamical behaviour, such as cloud formation and the clear air turbulence which shakes up airliners, might be more easily understood and predicted. A chain of events leading from the 1977 commercial flight to his recent instrumented flights of research over polar ice fields is infused with serendipity, according to Gary.

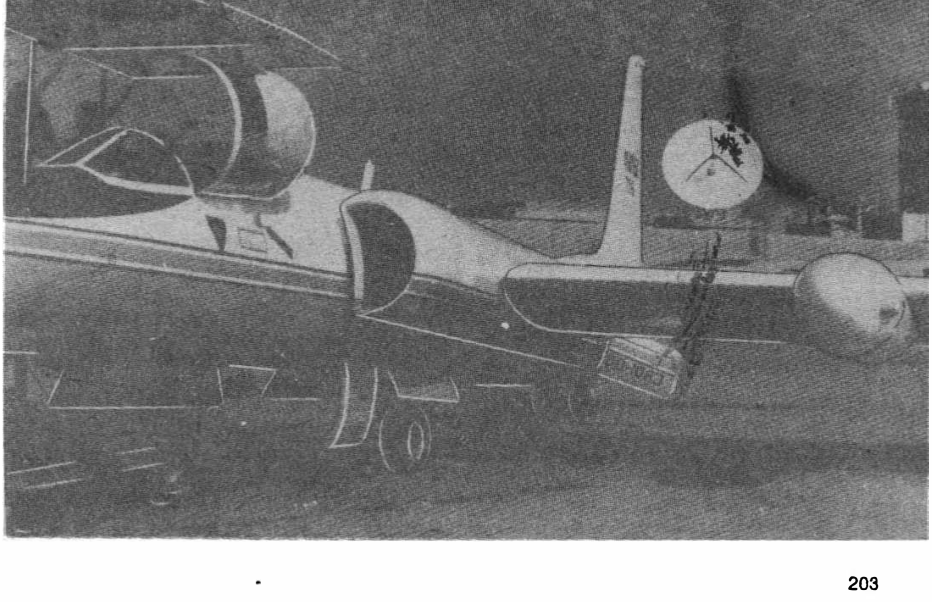
The Microwave Temperature Profiler (MTP) is Gary's answer to the challenge of obtaining temperatures at a distribution of altitudes in the atmosphere. The physical principle on which the instrument operates is the detection of microwave emission from oxygen molecules, which comprise about 21 per cent of the atmosphere by volume. Technically, it is a passive microwave radiometer operating at the frequencies 57.3 and 58.8 GHz, corresponding to a wavelength of approximately 6 mm. Thus, like a telescope it sits and waits for data to arrive, unlike active instruments (such as Magellan's synthetic aperture radar) which send out energy and then detect patterns and times of its return.

The MTP measures the number of photons per second at the receiving frequency and direction and thereby measures a quantity called "brightness temperature," which can be used to determine the physical temperature of the air at a specified distance along the line of sight of the instrument. When operated from an ER-2 aircraft at 20 km, the MTP measures air temperatures at about 1 km from the instrument with one frequency (58.8 GHz) and about 2 km distant with the other frequency. The mode of operation is to sweep the instrument's sensing antenna along an arc contained in a vertical plane and spanning ± 60 degrees from the horizontal. The MTP does not measure temperature continuously along the arc, which it traverses in 14 seconds. Rather, it pauses briefly at each of 10 points to accumulate enough photons to produce a respectable singal-to-noise ratio. Calibration is performed on every sweep using a microwave absorber of known temperature located a few centimetres from the antenna.

The MTP weighs about 25kg and mounts easily in a spear pod on the wing of a NASA ER-2 research aircraft (derived from the famous U-2 reconnaissance airplane employed by the military). Gary said that the MTP is the only airborne instrument of its kind, although microwave radiometers have been operated from the ground and installed in satellites. In fact, the MTP is a spin-off from an instrument carried onboard the Nimbus 6 satellite.

The original direction of Gary's studies was to develop techniques for measuring temperature profiles that might be employed in the direction of clear air turbulence, and to this end he flew a precursor of the MTP mounted in a Convair 990 aircraft of NASA in 1978, later transferring his operations to NASA's Kuiper Airborne Observatory, a modified C-141 which has made significant discoveries in astronomy. The microwave radiometer was also able to detect in real time the location of the tropopause, that temporally and geographically varying boundary between the troposphere - the lowest layer of air, in which most weather occurs - and the stratosphere; the tropopause usually exists somewhere in the region 10 to 15 km above the Earth's surface.

The Microwave Temperature Profiler (MTP), visible as a small cylindrical projection from the spear pod on the wing of a NASA ER-2 aircraft, has been used to measure atmospheric temperatures in support of ozone research over polar regions. *NASA/JPL*



Operation of the MTP in the ER-2 aircraft commenced with the Stratospheric-Tropospheric Exchange Program (STEP) conducted over Australia in early 1987. This programme, which owes much to Ed Danielson of NASA's Ames Research Center, was planned for the purpose of determining why the stratosphere is so dry compared to the moist troposphere. Data collection by the STEP team was successful but has not yet been analyzed because the recently discovered decrease in ozone over Antarctica was designated a high-priority research item and has absorbed the energies of investigators. The stratospheric layer of ozone provides protection against the harmful biological effects of solar ultraviolet rays.

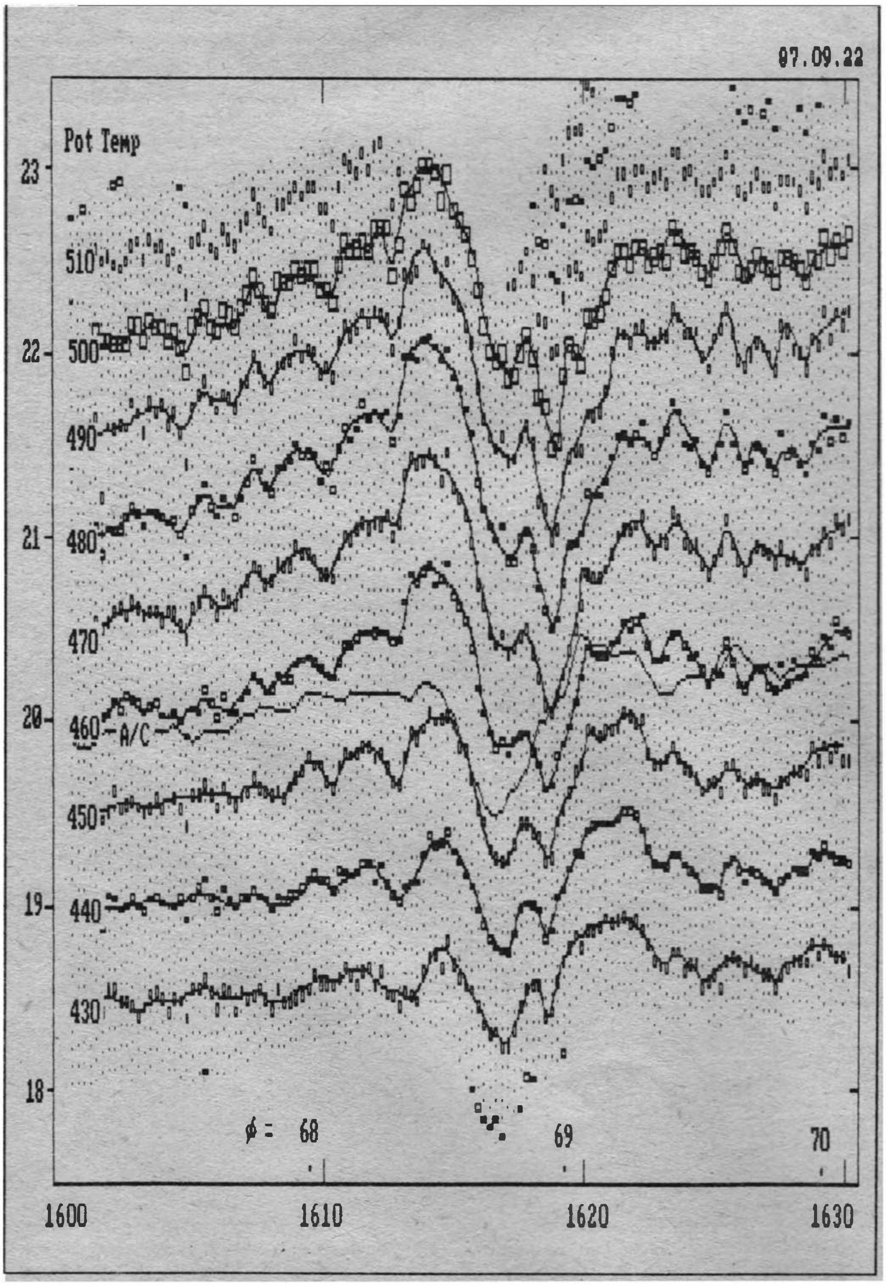
For 50 days, beginning in August 1987, 14 instruments were operated on an ER-2 flying over Antarctica in a multidisciplinary effort to investigate why ozone was apparently depleted from its stratospheric repository during the Antarctic spring. (Another expedition to Antarctica in September-October 1986, headed by Dr. Crofton B. Farmer of JPL and utilising a Michelson interferometer, is described in the December 1987 edition of this column.)

Gary's MTP was included in this suite of instruments for the purpose of locating the edge of the south polar vortex: the continent-sized swirl of air that circulates around the pole and which can be located through characteristic temperature and wind signatures at its boundary. It turns out to be most useful to convert MTP measurements to a quantity called "potential temperature": the temperature that the parcel of air would have if it were transported to the Earth's surface without exchange of heat energy ("adiabatically"). Surfaces of equal potential temperature are called "isentropes." While studying the edge of the vortex Gary constructed diagrams showing the altitudes of several isentropic surfaces versus time. Serendipity stepped in when he unexpectedly found large wrinkles in the isentropic diagrams. Normally such surfaces would more-or-less parallel the surface of the Earth. Correlating the atmospheric data with the ground track of the airplane revealed that the idiosyncrasies in the profiles faithfully tracked the presence of mountains; Gary had detected "mountain waves" in the stratosphere. Previously, it had not been known if mountain waves could propagate so far into the stratosphere and exhibit such large effects.

The significance of these waves is that a parcel of air, circulating with the polar vortex, moves along one of the surfaces of constant potential temperature and, encountering a mountain wave - a wrinkle in the mathematical surface - is lifted up about one-half km, then down one km and then back up one-half km to its original altitude, resuming horizontal motion. The parcel of air will cool in "real" temperature about 5 degrees Kelvin (although its potential temperature remains constant) during its initial rise in altitude, promoting the formation of polar stratospheric clouds.

The Microwave Temperature Profiler (MTP) was used to obtain measurements of "potential temperature" at various altitudes and geographic locations over Antarctica. Altitude (km) is plotted on the vertical axis and the time of measurement (aboard the ER-2 aircraft) on the horizontal axis. The large fluctuations in potential temperature represent "mountain waves" generated by the underlying topography and may play a role in ozone depletion in the polar stratosphere.

NASA/JPL



Polar stratospheric clouds (PSC) have assumed an important role in ozone-depletion studies since it is believed that they constitute a workshop where that ozone killer, chlorine, is generated. The original source of much of the chlorine is thought to be from man-made chlorofluorocarbons. (See the March 1988 edition of this column for a review of the pertinent chemistry).

The importance of the role of PSCs associated with mountain waves in ozone destruction has yet to be determined, but in addition to their potential for facilitating the production of chlorine, Gary said that they also may play a part in denitrifying portions of the stratosphere. Compounds of nitrogen, particularly naturally occurring nitrogen dioxide, neutralise chlorine and hence prevent its destruction of ozone. The cooling of an air parcel as it rises has the potential to form water-ice particles, wrapped around nitrogen-containing cores. If the ice-coated particles are sufficiently large, they will fall under the force of gravity out of the air parcel before they have the chance to evaporate upon being subsequently warmed: denitrification would have taken place in that layer of the stratosphere.

Late last year Gary left for the Arctic in order to conduct additional ozone-related studies. Mountain waves like those over Antarctica were not detected, but conversations with PSC theoreticians on the expedition revealed that the models they were using for simulating a parcel's temperature versus time were not consistent with data obtained through his MTP usages over the years. They had overlooked a component of short-timescale temperature fluctuations (which are apparent in the MTP data) that must be added to the slowly varying temperatures in their simulations. Since temperature histories are crucial to models of PSC formation, and hence ozone balance, Gary's introduction of the so-called mesoscale domain of temperature fluctuations has begun to influence our understanding of an important aspect of cloud microphysics.

The understanding of the extent and mechanisms of ozone depletion is a difficult scientific problem that is slowly yielding to a multidisciplinary, international effort. There is commitment as well as analysis in Gary's work: "We are just one species on this living planet, and we have a responsibility, by virtue of our powerful understanding and insight, as well as our role in creating the environmental threat, to take a caring custody of our planet, and of the other life forms with whom we should share in gratitude."

July 1989 US$3.25 £1.25

Spaceflight

The International Magazine of Space and Astronautics

Special Issue

THE FUTURE OF SPACE

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-7
(спейсфлайт)
По подписке 1989 г.

Apollo 11 20th Anniversary

Vol.31 No.7

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DISTRIBUTION DETAILS

Spaceflight may be received worldwide by mail through membership of the British Interplanetary Society. Details from the above address. Library subscription details are also available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by AGB Impress, Cloister Court, 22-26 Farringdon Lane, London, EC1R 3AU. Tel: 01-253 3135.

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Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published monthly by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L., Ltd., Aylesbury, Buckinghamshire, England.

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Spaceflight

The International Magazine of Space and Astronautics

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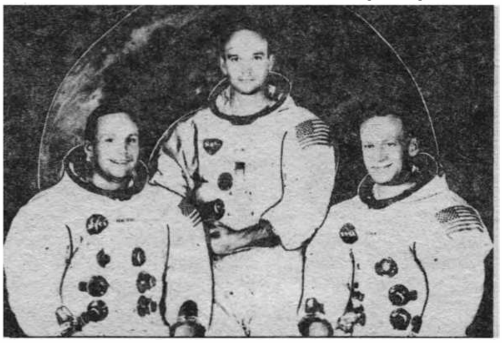
THE FUTURE OF SPACE

Apollo 11 Twentieth Anniversary Special Issue



The Apollo 11 crew (left to right) Neil Armstrong, Michael Collins and Edwin 'Buzz' Aldrin *NASA*

Buran Flies West

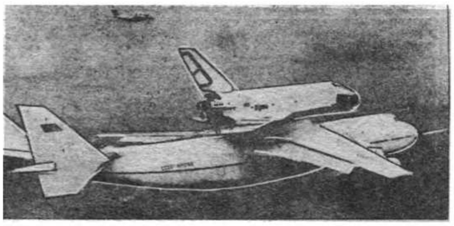
Soviet Shuttle at Paris Air Show

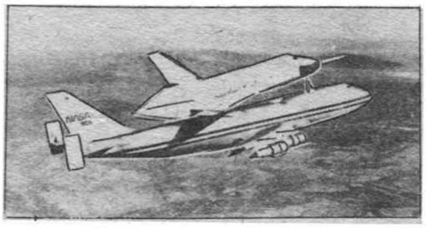
The Soviet Space Shuttle Buran made its first appearance in the West at the Paris Air Show, June 8-18. The spacecraft was ferried to the show atop the massive Antonov An-225 cargo plane.

The An-225, named Mriya (meaning dream), arrived at the Baikonur Cosmodrome in mid-May to pick up Buran. The shuttle was attached to three struts on the Antonov's fuselage. The combined vehicle carried out a number of test flights and on June 6 the An-225 and Buran took off on a non-stop flight to Paris.

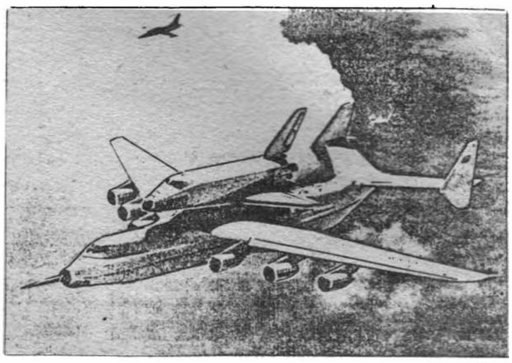
Unlike its American counterpart the Soviet shuttle does not use a tail cone during ferry flights. US Shuttles have their main engines shrouded within a tail cone to prevent damage to the engines and to avoid turbulence. Buran has no need for a tail cone: its has no main engines and turbulence is avoided because the An-225 has two twin vertical stabilizers mounted on each end of a vertical stabiliser.

Glavkosmos chief, Aleksandr Dunayev told reporters in May: "Buran has been completely restored and is ready for more flights." However, Soviet State Television reported not all of Buran's scorched surfaces had been cleaned and some of the tiles lost during her maiden flight have have not yet been replaced. Dunayev added the next mission would be conducted when there a was a payload that could, at least partially, make up for the costs involved. In a reply to a reader's letter in Komosomolskaya Pravda, Dunayev said: "There are no faults [with Buran]. We have simply started counting our costs and relating them to economic and technical expedency."





The sheer size of the An-225 is clear when photographs of the US Shuttle and its Boeing 747 carrier (bottom) and Buran on the An-225 are compared (top).



The Antonov Mriya and Buran during a test flight.

● During the 11 day Paris Air Show NASA exhibited a full scale model of the Hubble Space Telescope, now scheduled for launch in early 1990. Other exhibits included a 75 foot mock-up of the US National Aerospace Plane (NASP) and full scale mock-ups of the Hermes mini-shuttle, ESA's ERS-1 remote sensing satellite, the European Columbus attached and free-flyer laboratories for Freedom Space Station.

Soviets Give SL-16 Details

The Soviet Union has revealed details of the SL-16 Medium Lift Launch Vehicle. The two stage booster, named Zenit, is capable of lifting 13.7 tonnes into Low Earth Orbit. The vehicle is expected to launch a large cargo craft for space station resupply missions. Because the vehicle can be readied for launch very quickly (in about 80 hours), the booster could also launch manned craft for an emergency space station rescue mission.

Columbia Engine Leak

Engineers at the Kennedy Space Center have discovered a leak in a fuel pump in the No.1 main engine of Columbia. The pump is to be replaced. Launch Director Bob Sieck was unable to tell what effect the problem would have on the launch date, which is currently scheduled for no earlier than August 1.

Proton Stage Comes to Earth

A Proton rocket's third stage failed to burn up in the atmosphere as planned after its launch on May 31. Parts of the stage fell along the US-Canadian border. The Soviets have launched an investigation into the incident, which was reported by American officials. The Proton had orbited three satellites: Cosmos 2022, 2023 and 2024.

Galileo at the Cape

The Galileo Jupiter penetrator probe arrived at the Kennedy Space Center on April 17. The Galileo orbiter arrived a month later on May 16. They are undergoing checkout in the Spacecraft Encapsulation and Assembly Building No.2.

Shatalov Speaks Out

In a recent interview, Lt-Gen. Vladimir Shatalov head of the Gagarin Training Centre at Star Town castigated central planners for not providing the cosmonaut team with a plan for the future.

The decision to stand down the two teams training for the Soyuz TM-8 flight (prime crew Viktorenko/Balandin, reserves A. Solovyo Serebrov) was taken late in the training cycle Shatalov said.

He said that the crews would need to be trained for working with the new modules which were to be launched in August/September 1989 and later.

He also said that because of the delays in launching the modules some 50% of Mir's scientific equipment was not functioning and the interior of the complex was cramped due to the amount of equipment that had been delivered.

Shatalov called for the formation of a Space Agency of the Soviet Union to coordinate all aspects of the programme. It would be similar to NASA of the United States.

He cited the current system as an example of failure in long term planning. In the past this was the province of an interdepartmental scientific and technical council led by Academician M.V. Keldysh, President of the USSR Academy of Sciences. The council is now headed by Academician G.I. Marchuk. But, Shatalov said, "We are still waiting for results from its work."

Today, he said, the Soviet Union has "no programmes... I have no idea what we will have to do tomorrow or the day after. And even the current tasks are changing all the time. We still have no programme for specific training for, say, next year, never mind the more distant future."

Neville Kidger

NASA Names Crews for 1990 Military Missions

NASA has named Shuttle crews for two Department of Defense Shuttle missions scheduled for Mid-1990.

Air Force Colonel Richard O. Covey will command STS-38, a classified DoD mission aboard the Space Shuttle Atlantis, in May of 1990. Covey's pilot will be Navy Commander Frank L. Culbertson. Assigned as Mission Specialists are Marine Colonel Robert C. Springer, Air Force Major Carl J. Meade and Army Captain Charles D. "Sam" Gemar.

Named as Mission Specialists for STS-39, another DoD mission scheduled for July 1990, are Air Force Colonel Guion S. Bluford Jr., Richard J. Hieb and Charles Lacy Veach. The remainder of the seven member crew will be assigned later. The early assignment of Mission Specialists will allow payload training to begin.

Phobos Loss - Spacecraft Designers Blamed

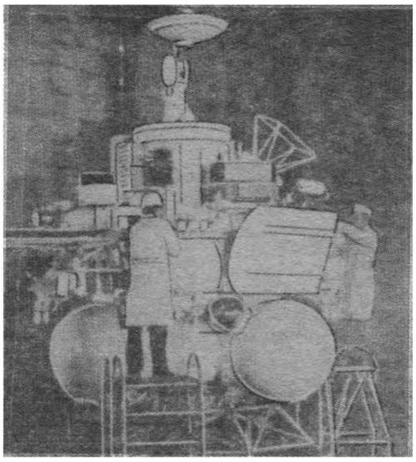
The loss of the two Phobos probes has caused much controversy in the USSR. The designers of the Phobos probes are being criticized by the scientists. ***Mikhail Chernyshov*****, speaks to leading Soviet space officials and asks what lessons have been learnt.**

Several months have passed since the completion of Project Phobos, but passions are still running high in the scientific community. So what happened to the two automatic probes which successfully started out on their journey to the planet Mars but never completed their mission. The special commission which is looking into the matter has so far failed to arrive at any definite conclusion. Conversely, the situation seems to be growing more complicated, and the decision now is to enlarge the commission by inviting foreign scientists in order to preclude any bias in the investigation. For the time being, let us look at the data provided by the Phobos probes.

The International Scientific Council on Project Phobos met in Moscow to sum up the first results of research relating to Phobos, Mars and the Sun - the three bodies which the joint programme was mostly concerned with. As for the study of solar activity, scientists consider it a great success that the Terek telescope, mounted on the first probe, had sent back to Earth a number of extremely interesting pictures of the Sun before its loss, including a picture of plasma shooting out at a distance roughly equal to the Sun's radius. The onboard photometer of the probe recorded more than a hundred outbursts of hard gamma-radiation.

In January-March of this year, when the second craft reached the vicinity of Mars, it transmitted data relating to Mars and Phobos. Altogether several dozen detailed television pictures of these bodies had been obtained. Ballistic and other measurements will enable a more accurate assessment of the Phobos orbital movement and its mass and the mapping of its surface. It turned out that Phobos minerals contain less water than was expected. Daytime temperatures on Phobos reached 27 degrees Centigrade.

The new data about Mars concerned, in particular, the Martian atmosphere and the plasma and wave processes taking place in the magnetosphere of the planet. The probes failed in what was their principal mission: they were to approach Phobos at a maximum distance of 50 metres and to do a high resolution photographic survey. Several major experiments had not



One of the two Phobos probes during final preparations. *Novosti*

been carried out either. So what are the factors behind the failure?

"The breakdown of the second craft is being attributed to extraneous causes, notably, a possible collision with a meteorite," says Professor Vasiliy Moroz. "Indeed, there may be a rarefied meteorite belt around Mars, but the likelihood of collision with a spacecraft is very low. I think it was just that the systems were not good enough. They might have overheated because of the strenuous work schedule."

Says Academician Roald Sagdeyev: "Of course, the participants in the project, who come from 13 countries and who carried out experiments using tax payers' money ought to have given an explanation in their countries as to what exactly had happened to the two craft. But, within the first few weeks of the failure of the mission, there were only hints that the craft might have come into collision with something. At the meeting of the International Council, we, at long last, heard statements by the developers of the crafts' main systems. That was the first time that the general and chief designers spoke before a scientific audience. And we agreed on the need to set up an international working group that would sum up the results and analyze what had happened. In any future missions, an international group concerned with spacecraft survivability will be in place from the outset, right after the outline of an international project has been defined. I see it as a further step in promoting greater openness.

"On Project Phobos, we were at odds with General Designer Vyacheslav Kovtunenko, who blames the breakdown on extraneous factors, whereas we are taking a different view. I think a joint inquiry would shed light on the matter. The first and second craft were both lost in a very similar way. In the case of the former, an operator's error on Earth caused the craft to go off course. In the latter case, some malfunction in the onboard systems led to the same result. However, a really foolproof design must return the craft to the original position in a contingency. Something like that happened on the Vega-2. Thirty minutes before its rendezvous with the nucleus of Halley's comet, its computer guidance system broke down. But a similar backup system was switched on, and the rendezvous was successfully accomplished. Regrettably, such options were not available in the case of the Phobos probes. I hope that, in the future, space technology producers will have their absolute freedom restricted so that the world scientific community, as the end user of this technology, can have a say in decision-making on spacecraft design.

"At present space programmes are having a difficult time. Deputy Boris Yeltsin, for one, has proposed shelving them for 5 to 7 years. This is a serious matter. In addition to nuclear-phobia, there has emerged a space-phobia. It is not just a question of economic difficulties. The fact is that there is no openness as far as spending on particular projects is concerned. In my election platform, I urge the re-establishment of the popular belief in space science and exploration through truthful information. I will press for the publication of the space budget and spending on particular projects and activities. Nothing short of open debates will convince the public of the need for such work. I am positive that we must not throw overboard what we have already created. But a number of projects may seem to be before their time. For instance, there appears to be nothing at this point to justify the outlays for the reusable spacecraft Buran."

"Space technology designers," says Roald Kremnev, one of the men behind the Phobos craft, "have to comply with a set of restrictions relating to funds and the weight and size of spacecraft, etc. Of course, Project Phobos has taught us a lesson, and we are determined to rectify the defects we have identified, notably, those relating to power supply , operational errors, and the possibility of probes functioning in an automatic mode. Actually, I think such craft are capable of efficient performance." ***APN***

Progress 41 Reentry: Another Soviet Space Mishap

The unique re-entry of Progress 41 - four days of autonomous flight - was noted in last month's ***Spaceflight.*** **Analyst Phillip S. Clark has provided an explanation in the absence of official Soviet clarification - the craft ran out of propellant!**

Working from data supplied by the Goddard Space Center, Clark has derived the following:

Between April 9 and 17 two manoeuvres were performed by the Progress 41 spacecraft to place the Mir complex into a higher orbit. The complex was being stored in the higher orbit due to the enforced need to fly the station in an autonomous mode for a period of about three months following delays to the launchings of the add-on modules for the station (see *Spaceflight* June 1989, p.191-194).

Progress left the complex in an orbit of 373 x 416 km after the April 16/17 manoeuvre. (The Soyuz TM-7 engine was later used to raise the perigee to 388 km).

Progress 41 undocked at 0146 GMT on April 21. Firings of the engines after this time gave this history of the decay:

April 21.38 orbit was 213 x 417 km
April 21.50 orbit was 191 x 410 km
April 21.63 orbit was 124 x 390 km

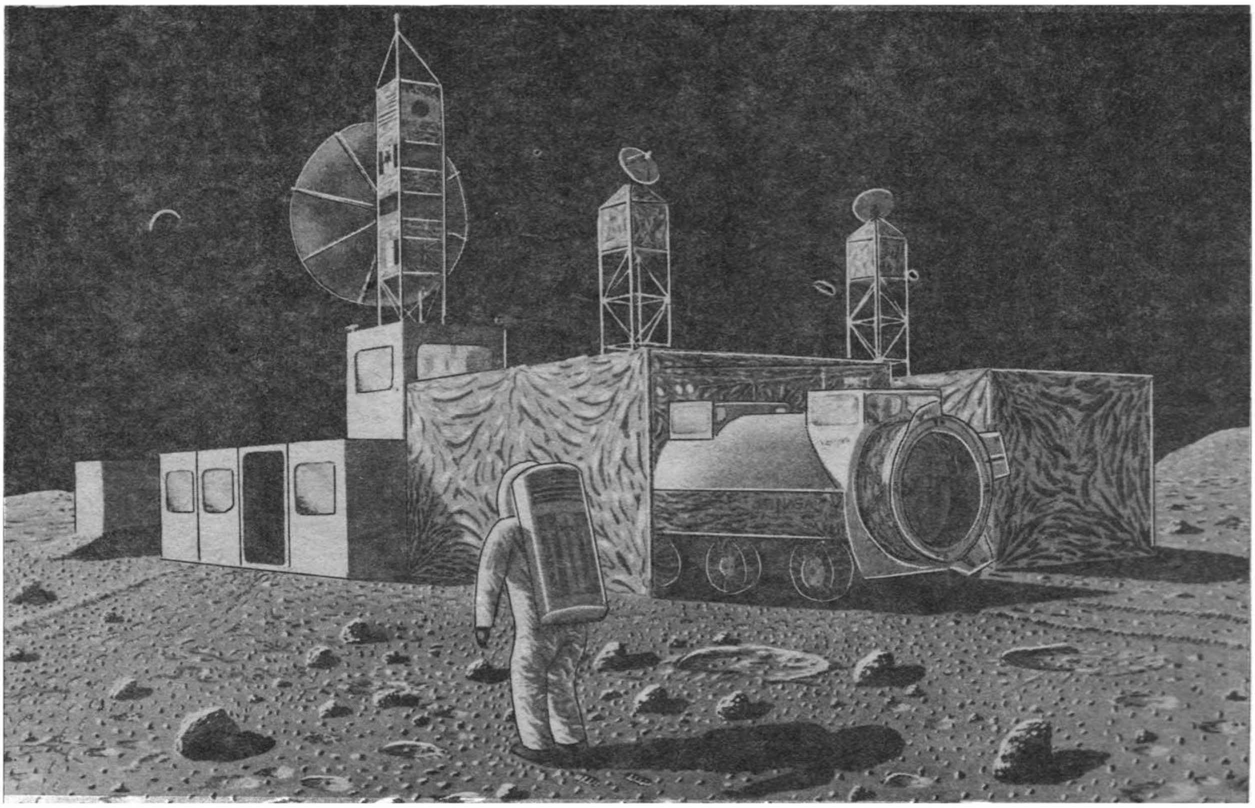
After the failed attempts at re-entry the orbit decayed naturally, and sharply, until, at April 25.33 the orbit was 105 x 203 km. Clark's analysis of the Goddard data shows that at April 25.51 (i.e. midday GMT) Progress 41 was in an orbit of 92 x 150 km.

TASS later announced that Progress 41 has entered the Earth's atmosphere at 1202 GMT April 25.

If the delayed, and hence uncontrolled, re-entry of Progress was due to running out of propellant it illustrates the degree to which the rapid decision to terminate the permanent manning of the Mir complex affected mission planning.

Neville Kidger

Cities on the Moon - A Lost Vision?



A concept for an early, permanent, ten man international lunar base from prefabricated sections ferried from Earth. BAe

Twelve years after Columbus discovered America, Breton fishermen were trawling the cod banks off the coast of Newfoundland. Thirty years later, Cortez was engaged in the conquest of Mexico. The human race first landed on the Moon in 1969. Apollo 17 left in 1972. Since that time there has been no return. Nor, at least in the Western world, are there plans to return in the remaining years of this century. Yet if we look at the parallel with Columbus, we should have returned to the Moon by 1981. We should now be planning for the start of permanent Lunar colonies by the end of the century.

By Dr. R. C. Parkinson

The prophets of astronautics in the 1950s saw a natural succession of developments. First we would build a reusable, regular Shuttle launcher to take men and equipment into low Earth orbit. (They didn't call it a Shuttle, and by regular they meant perhaps once a week, not six or eight times a year, but they had the scale right). Once established in orbit, we would build a permanent space station to act as an observation point and a construction site for ships to take us further. We would build true space ships in orbit, unfettered by the need to lift structures through the Earth's atmosphere and to carry wings and protection for re-entry. From the staging point of the space station we would move onward to the Moon. Initially the exploration of the Moon would make temporary encampments, providing stays of six weeks or so. But we would quickly convert from a temporary to a permanent base with a stockpile of resources, and from there we would move outward. Soon we would learn to use the resources of the Moon and found permanent colonies. One day there would be Cities on the Moon, with inhabitants who were born, lived, worked and died there.

What went Wrong?

This isn't simply an article about what went wrong with the vision of the Founding Fathers of astronautics. The Moon remains the most important natural resource in our sky. If we are to exploit space, if we are eventually going to leave our planet behind, we will need to learn to use what the Moon offers. The findings of the Apollo missions have not altered that. There is oxygen on the Moon, extractable as rocket propellant, and capable of being transported into Earth orbit for a fraction of the expenditure of energy required to lift material from the Earth's surface. There are construction materials - basalt fibre as tough as glass fibre, and chemical engineers will give you schemes for the recovery of titanium and aluminium from surface rocks. Even nickel must lie below the asteroid impact craters scattered across the lunar surface as it does on Earth. If we are eventually to build large structures in space, it will be easier to do it with Lunar industry than launching from Earth. Orbital industry on a large scale will have to draw on the Moon for its stocks. And as an energy resource, if clean fusion power eventually comes, it may need a ready supply of helium-3-atoms which have been gently deposited over millennia in the surface dust of the Moon by the Solar Wind.

Yet the world seems to have few plans to return to the Moon, let alone build permanent bases, colonies and industries on its surface. Why?

I believe that the answer to that question reveals rather more than why the richest nation of the world won

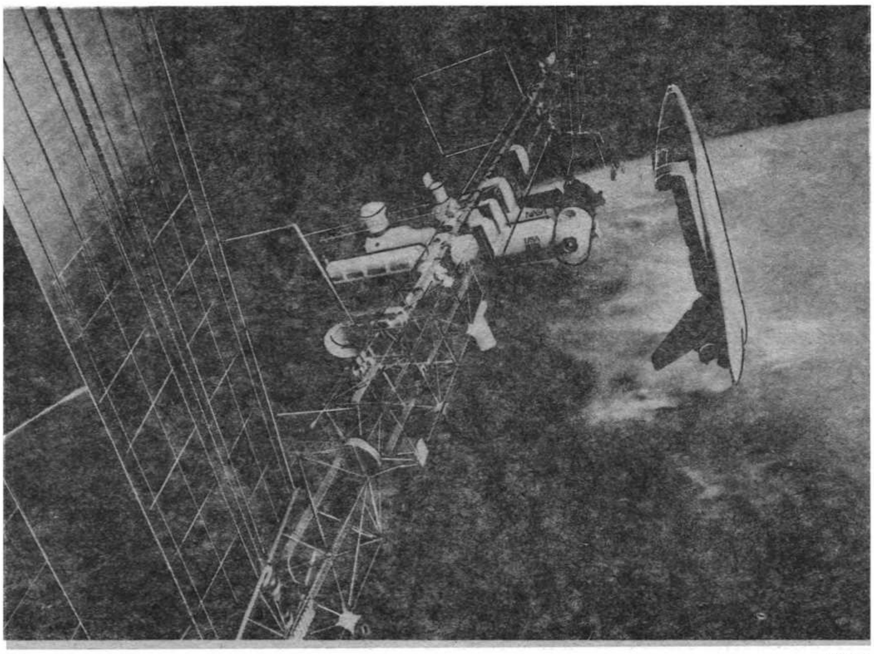
the race to the Moon and then spurned the prize. I believe that the same problems continue to bedevil "European Space", and have relevance to the attitude taken by a "poor country" (in space terms) like the UK.

One reason for the demise of Apollo was the cost. Each Saturn V launch, in modern-day terms, cost in excess of one billion dollars. Even the USA could not afford to keep such an expenditure going for long without very positive returns. Yet, in less than a decade, the USA had found $40 billion to invest in Apollo. Had it spent a similar amount over the next two decades in reducing transport and operating costs, the price for a ticket to the Moon today (or say by 1992, for the 500th anniversary of Columbus' landing in the New World) need have been no greater than that for a current Shuttle flight into low Earth orbit. It would probably have been less.

That much was in NASA's plans in 1970. The Space Shuttle was aimed at bringing costs of transport into low Earth orbit down to $300/kg. With hindsight, that may always have been unrealistic. Even with our studies on HOTOL we believe that a realistic target lies in the range of $500-$1000/kg. But the basis on which we calculate costs today are far sterner (post-Challenger) than those used by NASA in 1970. And achievable launch costs are still well below the actual $5000-$10,000/kg for a Shuttle launch.

Coupled with the Space Shuttle in the 1970 plans was a reusable, cryogenic, European Space Tug intended to extend low cost access to space as far as Lunar orbit. The cost of cargo on the Moon need have been no more than four or five times that in low Earth orbit. Furthermore, NASA had plans for a modular Space Station which, if not to the scale of the current $20 billion Freedom International Space Station, would certainly have matched the Russian Mir as a staging point in low Earth orbit, and for a quite moderate cost.

It is hardly necessary to review what went wrong. With restricted development budgets, successive decisions made in the Space Shuttle design abandoned the target of low operational costs. Without the Space Station (which in 1972 need have been no more than a second Skylab) the Space Shuttle had to turn into a miniature Space Station of its own on each flight. European participation was diverted from the Space Tug to Spacelab, to provide an extended laboratory capability for the Shuttle which, with a Skylab station in orbit, would not have been needed. Transport beyond low Earth orbit was restricted to inefficient and expensive solid stages, and a reusable cryogenic Tug (now that Shuttle-Centaur has gone) still lies a decade or more in the future. The path to low cost Space Transportation was certainly more difficult than envisaged by George Muller in his historic speech to the British Interplanetary Society in 1969, but decisions and events made in the meantime have meant that it is no longer even possible to evolve towards such an objective. The Shuttle operations are cast in concrete and steel, and while it is a brilliant technical achievement, future low cost launchers will not build on it so much as bypass it.



Space Station Freedom will set the standard for future spacecraft for years to come. NASA

It is the glory of things which have never been done before that command funding.

Cost was one factor in the abandonment of Apollo, but not the essential factor. The planned scientific programme was incomplete. Indeed, the first trained scientist on the Moon - Harrison Schmidt - did not fly until the final Apollo mission. At least three more Apollo missions were planned - the objectives defined, the hardware paid for - Saturn V vehicles were abandoned in mid-construction. Even more telling - there are other, cheaper ways of returning scientific information from the Moon, post Apollo, but none have been taken up. A lunar polar orbiter would give detailed geological information about the Moon - essential information for future colonists - for the price of a modest unmanned space-probe. It has been proposed several times since 1972, but remains unfunded.

Despite the fact that it revealed a more interesting world than we had imagined, Apollo did not encourage further exploration. It actually inhibited it.

Not only lunar exploration suffers this way. Mars has not been visited since Viking. Mercury lies untouched since Mariner 10. It is not that there is no work to be done, it is the spectacle of achievement that is missing. While politicians and administrators listen patiently and with polite interest to carefully thought out and cost-effective programmes presented by the scientists, the words mainly serve to assure then that their money is not being mis-spent. They have little interest in progressive plans for space exploration. It is the glory of things which have never been done before that command funding.

Unfortunately, for space programmes which are done for glory and not for simple commercial gain, this attitude seems likely to stay. And it brings with it two problems which continue to bedevil us.

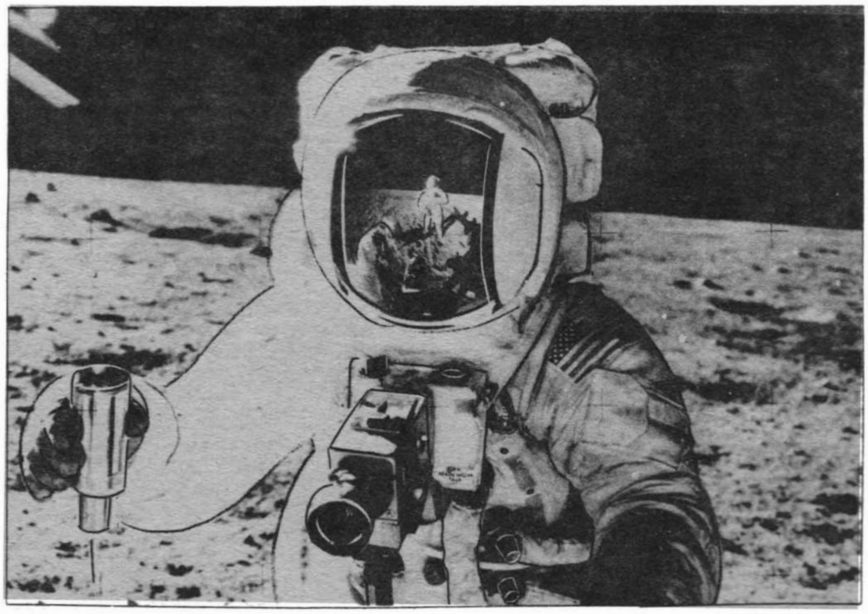
The first problem is that if each new thing we do in space is done because it has never been done before, because it is difficult and shows off our cleverness, then the impetus to reuse systems and hardware, to design spacecraft and launch vehicles for the long term is reduced. The Apollo programme was a prime example. NASA built hardware dedicated to a very specific mission. It performed that mission admirably, and then turned to something else. Skylab succeeded

because it ingeniously used left over hardware to score another first, but like Apollo it was not allowed to lead on anywhere. The Space programme is littered with one-way examples. The engineers and planners are only too aware that such economics are senseless. Multi-purpose spacecraft which can be used for mission after mission, with relatively low costs after the initial development, are proposed regularly. But programmes are funded on a one-at-a-time basis. That front-end funding is important, and commitment to doing the same thing twice is quite missing.

Looking to its future programme, and as a background to the "Pathfinder" technology development programme, NASA has made studies of potential ways of putting a Man on Mars as a "long term goal". Ivan Bekey described some of these studies at Space 88. It is apparent that these studies continue to follow this philosophy. The possibility of exploiting lunar resources has been looked at - but only as a cheaper way of getting one manned mission to Mars, not as a long term investment to our whole future in space. Not surprisingly, given the terms of reference of the study, the initial conclusion was that exploitation of lunar resources was probably not cost effective. But the objective was to repeat Apollo, this time on Mars.

The second problem follows. If difficulty and spectacle are drivers for governments to put money into space, then it does not matter very much that space is expensive despite lip service given to the idea. Those governments which want glory from space will want to demonstrate that they command the resource and the will to do such things. (Furthermore, since it is a hugely glamorous thing to do, there are thousands of scientists and engineers who will flock to such enterprises and help demonstrate - for a price - the scope of their ingenuity and expertise). Those governments which see no profit in glory, on the other hand, will suspect that the large investments needed to make space activities cheap and affordable are excuses for spending vast sums on space in another guise.

I detect this sort of process in the current European activity on Hermes and Columbus. French engineers are quite clear that the more modest cost of a Gemini-style ballistic capsule to carry men into space and service the Columbus Man-Tended Free Flier would not command the funding which Hermes has acquired. The United Kingdom, briefed to take a moderate and cautious line, instead simply abandoned European space to its fate. There is now a danger that, if the German Columbus MTFF and the French Hermes cannot be reconciled, or become unaffordable, the consequence will be not a return to realistic proposals, but a catastrophic collapse in European interest in space.



An Apollo 12 astronaut holds a container of lunar soil. The Apollo programme proved Man could work on the Moon. *NASA*

The traditional assumption has been that space exploration will naturally be followed by space exploitation. Exploration represents the desire to do difficult and expensive things first, and can be funded as national goals. Exploitation makes a profit and is naturally funded from commercial sources. But this expectation misses a stage. Exploitation only follows the establishment of an infrastructure. And to date, the explorative motive has been notably unsuccessful in establishing a commercially viable infrastructure.

The one spectacularly commercial return from space has been in telecommunications. The returns were so obvious and so large (putting the satellite in geosynchronous orbit costs only about 2% of the revenue it generates), that President Kennedy founded intelsat to stop commercial warfare between the industrial communications giants. Nevertheless, even with the multinational resources it had at its disposal, Intelsat has not even partially funded the development of one launch vehicle or even an upper stage.

The reasons why commercial ventures are unwilling to found infrastructures is twofold. One is that all the possibilities for exploitation are not apparent until the transport and handling infrastructure is in place. The second is that there is a political dimension - infrastructure defines the channels of power in the new territory. Develop an infrastructure for commercial ends and your profits are at the mercy of those who wish to use the infrastructure for other, political ends.

Actually, exploitation of the possibilities provided by an infrastructure demands not only the existence of that infrastructure, but confidence in its future. Prior to the Challenger accident, such confidence was beginning to develop with the Space Shuttle. As a consequence a variety of commercially funded space exploitation ventures were beginning to emerge. The Challenger accident threw the Space Transportation System firmly back into the political arena, and the commercial ventures based on it are now dead. Such confidence will be more difficult to establish the second time around, even if the Shuttle becomes available for such enterprises.

It appears that Space Exploration has ceased to provide the requisite long-term infrastructure needed for Space Exploitation. Those things that can be done with expensive, throw-away launchers, will be. That includes telecommunications (although some telecommunications applications are undoubtedly inhibited by costs still), Earth Observation (if the question of getting people to pay for things they expect to get "free" can be solved), and possible some very exotic micro-gravity products. The things which cannot be done for the price are obviously not worth doing. And so space will remain a playground for the very rich.

Recognising that settlement of space is a goal might help to change that. If we could design new systems just a little bit beyond the local Spectacular towards a belief in a long term future Space Development might build towards a consistent long-term

infrastructure.

Let me mention a couple of little things. The US Freedom Space Station project will set some standards for a long time to come. The docking hatch is one. Things that visit the Space Station will have to have a compatible docking interface. Things that they dock with will also. Whatever replaces the Space Station will still need to provide compatible docking arrangements. The Space Station hatch could well set the dimensions of the hatch of the Starship Enterprise. The hatch will eventually provide interfaces for vehicles operating on the Moon - operating under gravity conditions. Yet such long term objectives were not considered in the detailed debates within NASA, and certainly would not have been considered prime reasons for decision making. As a consequence, long after the world has gone metric there will be a funny-sized hatch on every spaceship. Rather as railway gauges were set by Stephenson's coal trucks, remaining a problem for every carriage designer for the next 150 years.

The railways are a good example. For over a century they provided the central transport infrastructure for the developed world, and it was possible to evolve a steady series of developments which improved efficiency, speed and pulling power without ever having to abandon what had gone before. We need to learn how to do the same exercise in space.

How do we build systems which will last? Logically the hard-won experience of Spacelab should have progressed directly into the Space Station module. In practice the sub-systems of Spacelab were old before it made its first flight, and even on the European Columbus Module the inheritance from Spacelab will be marginal. Electronic systems are particularly vulnerable in this way. But we cannot afford to redevelop launch vehicles, orbital modules and upper stages every fifteen years or so when it takes that long to get the financial decisions and carry out developments.

Let us agree then what the pioneers of astronautics knew full well. After the Space Station we need a Lunar Base. We need to start the Lunar Base programme soon enough to exploit the technologies and components won for the Space Station. There is not a need for a long preparatory programme - we could set the location for a permanent Lunar Base site today as a centre for exploration and exploitation if we cared to. But we need to reflect the Lunar programme potentials already in the Space Station programme. Then, when we begin the Lunar programme, we need to build a permanent facility with an emphasis on long-term industrial benefits, and we need to ensure that its architecture reflects the following step - Mars.

The opinion makers have tended to talk about goals in space, missions and objectives. We have become coy about the real reason we want to go. We have lost our Cities on the Moon because we feel that they may not be credible to the outside world. But that is the long term goal, and if we become serious about it then some of the shorter term goals might become easier. And one of the messages that we must get over to the decision makers is that space is not an arena for large and expensive projects, but needs more and more efforts into making access cheaper. Only then will our children be able to afford to build and live up there in the sky, and use the resources of space to solve Earth-bound problems.

Space Industrialisatio[n]

Even the earliest pioneering thinkers assumed that industrial applications would eventually become mankind's most important activity in space. In the event space technology found early commercial applications with communications satellites and, more recently, Earth observation systems. The next step will undoubtedly be small-scale manufacturing of space processed products. Indeed, one of the main reasons for orbiting laboratories such as Mir and Shuttle/Spacelab is to explore the potential of microgravity processing, thus leading to the first "made in space" products.

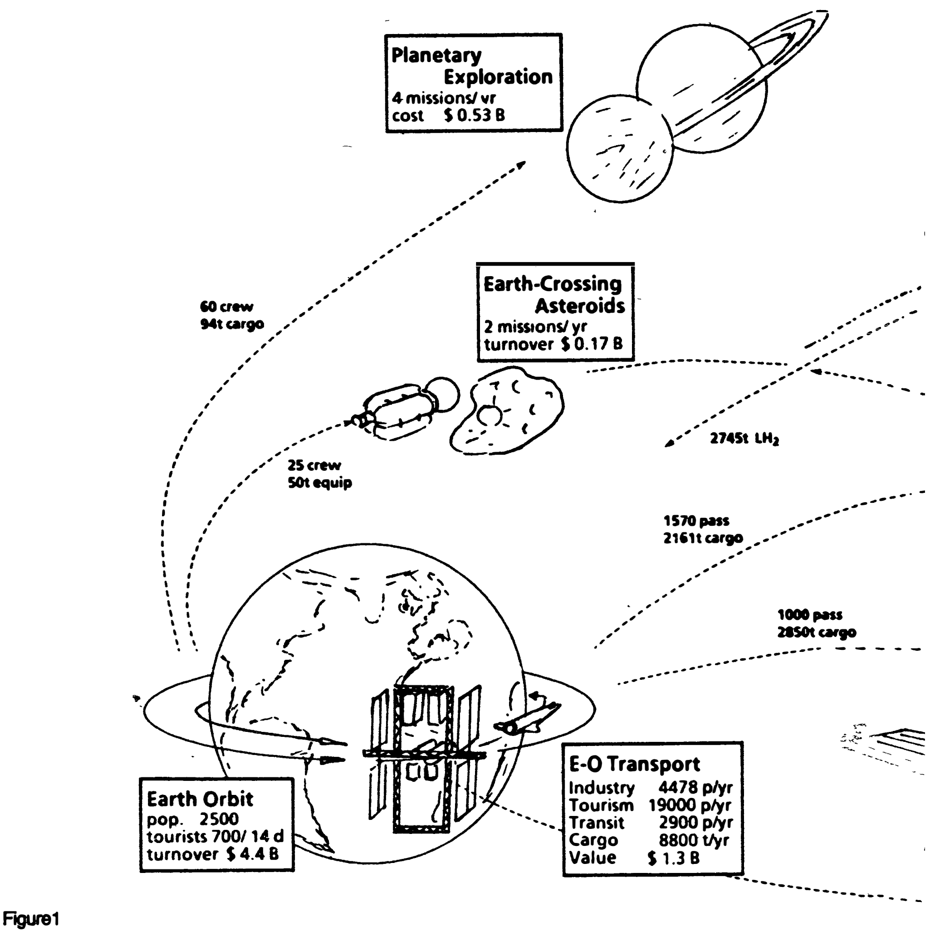


Figure 1

By Mark Hempsell

These first commercial products will involve very small production runs of high-value items such as drugs, large pure protein and semiconductor crystals and advanced structural materials. One example which has already proved viable is the production of very small but perfect spheres used for calibration purposes. These first products represent valuable business and will, no doubt, profit those countries that show the foresight to invest in the necessary technology.

How important is space industry? Much of past discussion regards it as just another business opportunity, a desirable but optional extra for a developed economy. However, recent studies which have examined the long-term development of this embryonic technology suggests that the industrialisation of space is far more than just another shrewd investment; it is crucial for the continued survival of our technological civilisation.

The chain of work which led to these conclusions did not begin with the intent of considering the future of spaceflight at all. A number of studies were performed in the late 60's and early 70's using computer simulations of the total world system [1]. These showed that the depletion of vital resources and the accumulation of pollution effects are linked to increases in population and standard of living. The models predicted growth continuing until early in the next century but after that the effect of pollution and resource depletion constrain growth and cause a rapid decline to medieval levels or lower. The solution proposed by the early researchers was to undertake a retreat into a "Post-Industrial" society, which would lead eventually to the same low economic levels but more gradually and in a more controlled manner.

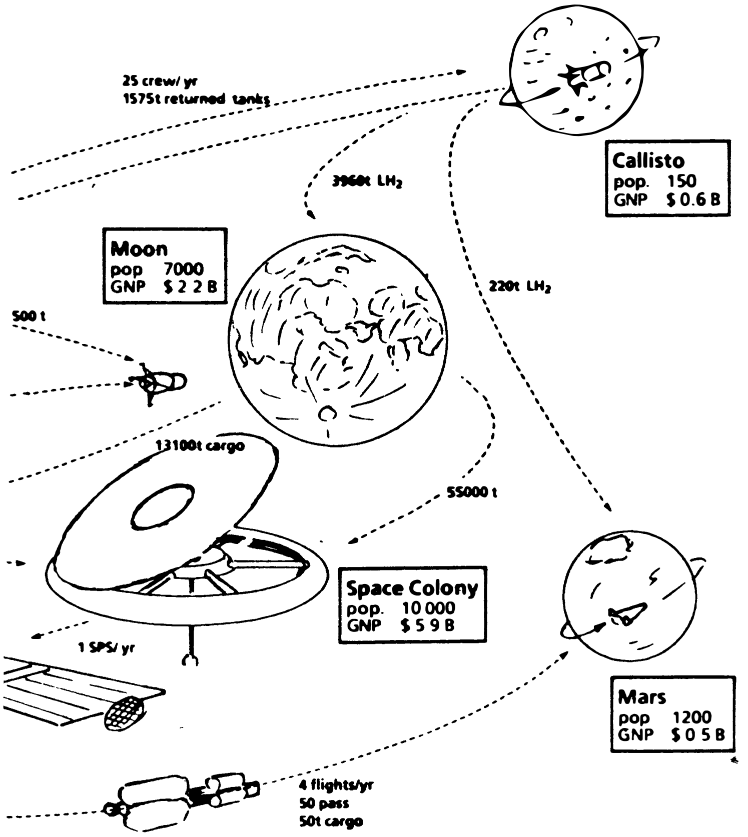
Not unexpectedly, these conclusions were unattractive so it is not surprising that those looking for alternatives explored the impact of the continuing advancement of technology on the computer models. The most famous of these responses was the work by Kahn at the Hudson Institute [2] which showed that technology could significantly alter the predictions made by the models. However, these "technological fixes" are generally vague as to which technologies will really achieve the two effects of increasing resources and reducing pollution. From this viewpoint, the most satisfactory of the new investigations (i.e. those providing the most detail and the most sustained growth) are those which consider the impact of a major space economy, able to provide a new source of raw materials and a sink for pollution and yet not affect the Earth's biosphere.

The earliest specific use of space in these models is attributed to Peter Vajk. He was largely sceptical of the computer modelling technique and was using the space inputs to economic models as a "parody" of the Club of Rome work "to show that such models can be used to 'prove' any conclusion you like" [3].

At the British Interplanetary Society's Space 1984 Conference, Dr. Tony Martin provided a talk which outlined the conclusions of his work on the effect of such space industry [4]. He took the modelling more seriously and showed that it pointed to only two alternatives for mankind, either a space age or a stone age. He demonstrated the urgency of establishing space economy by the second half of

A New Perspective

SPACE 2050 AD



the next century, otherwise it will come too late to save civilisation. The volume of space activity needed is not clearly defined in Martin's work but it was clearly substantial. More recent work by F.W. Schultz [5] shows the need for almost a third of all industrial investment to be in space-based business ventures.

Figure 2 (p.226) shows two projections into the future. The first is by Forrester of MIT which is, essentially, an indication of what happens if we do nothing. For the immediate future population will continue to increase, as will the average standard of living, but these lead to an increase in the consumption of material resources and the level of pollution. By around 2020 the impact of these last two factors start to constrain the first two, so population and the average standard of living start their irreversible decline.

The second projection is by Martin. This analyses the impact on the original projection of a space industry addition to the model which increases the material resource base and acts as a sink for pollution, both features being introduced during the second half of the next century. The effect is again dramatic. Population, after a slight dip, once again continues to grow and the material standard of living also steadily increases.

The global system modelling technique is clearly too simplistic to provide an accurate prediction tool. However, the overall picture shown must be taken seriously. Different models have been created by other researchers which are more complex than the original Forrester model shown in fig. 2, but all have produced similar results. In any event some of the predicted effects can be seen at first hand in the real world. In the 20 years since the Forrester models were first produced, the population has grown a little faster than predicted. Some of the dramatic effects of pollution are apparent in recent events such as the depletion of the ozone layer, acid rain destruction of the northern temperate woodlands and the greenhouse warming of the atmosphere. One can even see the beginnings of a major decline in resources such as oil.

The broad conclusion of these studies is that, in the second half of the next century, there will need to be a massive movement of industry into space, if we are to maintain our current civilisation. The question then arises of how will this happen? It is unreasonable to assume any major change in Society's economic structure over the next century, so each new space factory would need to be constructed on a commercial basis, driven there by a carrot and stick effect. The carrot will be the freely available energy and resources which will become increasingly rare on Earth. The stick will be the Draconian legislation which will be required to keep industrial activity compatible with the Earth's ecology.

If major companies are to make such decisions, the space option must be viable. When setting up a factory on Earth, viability is assessed on such factors as transportation links, power utilities and workforce availability. These factors are generically referred to as "the infrastructure". The same will be true in evaluating the economic viability of a space factory; it will be assessed on the extent and efficiency of the space infrastructure in place.

The next stage in the argument is thus to establish what infrastructure has to be in place around the middle of the next century so that expansion into space is both a viable and economically attractive commercial option. It must be attractive not just for specialist processes that can only be done in space but also for products where it is merely more desirable that they be processed in space.

Dr. R.C. Parkinson has been modelling a possible space economy around the year 2050 [6]. The work uses a technique called input/output modelling and was not originally intended as a follow-on to the global modelling work. Parkinson was interested using this relatively new economy modelling technique to get an insight into the way an economy could develop within the space infrastructure. However, its results forward our understanding of the implications of the global models. What needs to be in place is an infrastructure that makes it economic for moving industry into space. The Parkinson model shows the transport cost, wages, and other important factors. It is useful as it provides a link between pure economics and the technical features such as the size of facilities, the prod-

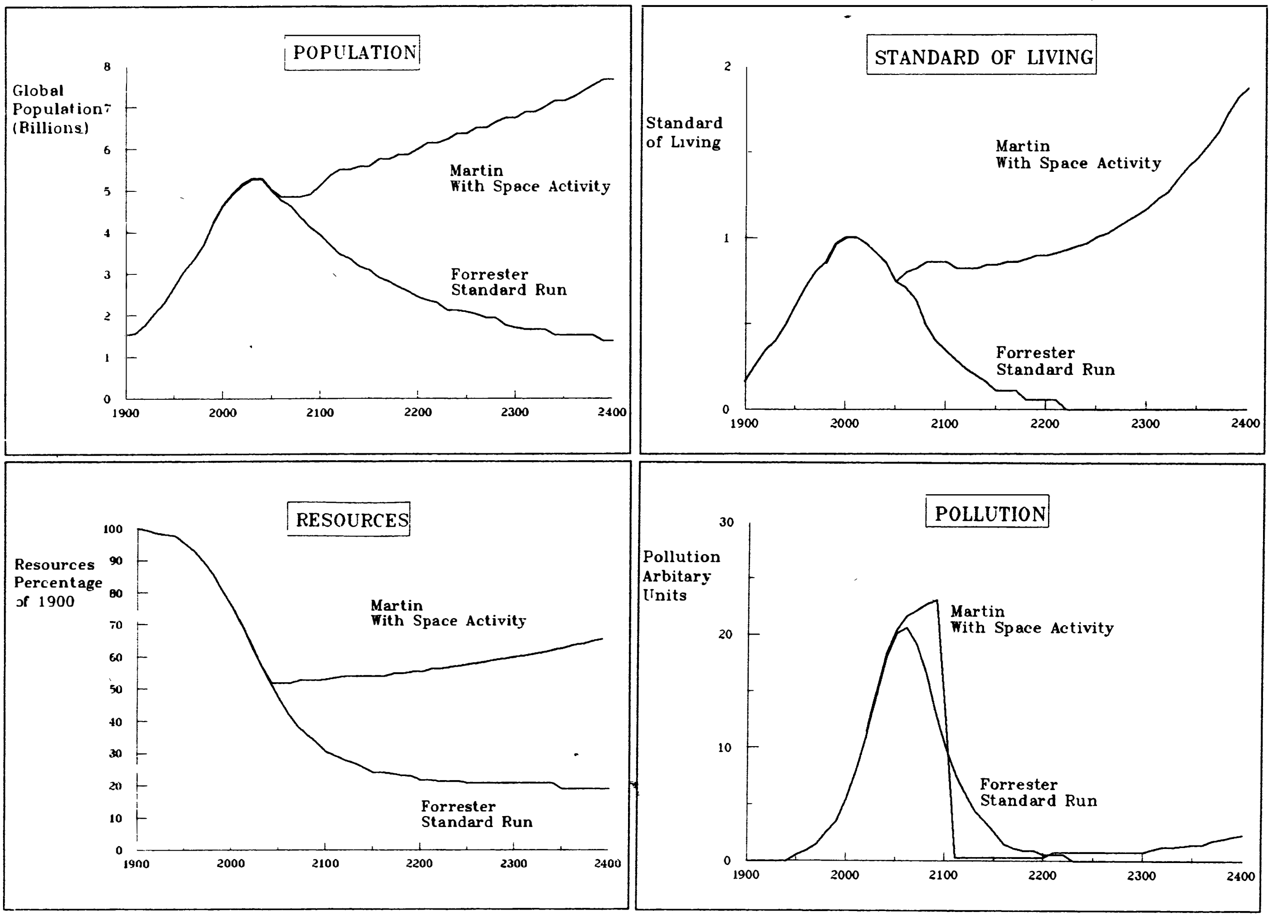


Figure 2 :Comparison of Global System Models With and Without a Space Economy.

ucts and the technologies used.

The Parkinson model (fig. 1) has all the main types of activity required. However, it is nowhere near the scale of activity required. From the Parkinson model in 2050 with a Gross Space Product of around $15 billion to a Gross Space Product a thousand times greater in the year 2100 would suggest that the growth in the space economy in the second half of the next century would average 20% per annum. When this is compared to current national economic growth rates, typically 2% to 3% p.a., the scale of the problem can be appreciated.

The Parkinson model can be viewed as the absolute minimum that needs to be in place by the middle of the next century if mankind is to have the option of a space future.

Currently, new space infrastructure elements are introduced in the West every 15 to 20 years. There are only 60 years until 2050 and it is clear that much more than 3 or 4 programmes of the Space Shuttle or Space Station type are going to be required. The pace of the Western space effort will need to be substantially accelerated if we are to get anywhere near this target.

Some of this effort may be commercial, though it is difficult to predict at present which steps could be commercial and which would need to be directly funded by governments. As a general rule, the less the government invests in the early stages, the less opportunities for commercial activity arise and the more government will need to invest in the later stages. Conversely, the more the government invests in the early stages, the more business opportunities arise and the commercial sector becomes more confident and willing to invest capital.

This can be seen by looking back to a long-term programme put forward in the United States 20 years ago. In 1969 NASA proposed the Post-Apollo programme which covered 20 years from 1970. By 1990 there would have been Space stations, Lunar and Mars bases, all large facilities with 50 to 100 people. The growth that would then have been required to reach the 2050 target from this start would have been about 8% per annum. At this level the majority of the growth activity would probably have been commercial. NASA estimated annual budgets for the Post-Apollo programme at the same sort of level as during the peak of the Apollo programme. This would have been about twice the actual funding level over the period.

However, the Post-Apollo programme never happened and new long term programmes are now being proposed. The National Commission on Space report [7] and the Ride report [8] both like the Post-Apollo before them, offer a vision of Lunar bases and manned flight to Mars. The pace of the two proposals is different and the scale of the activity a little vague in both, but they could lead to bases and stations of several hundred people in the various locations by 2020. If this took place, then growth over 15% per annum would reach the 2050 target. In this case it is unlikely that so much of the growth activity could be commercially sponsored, as would have been in the case of the Post-Apollo.

Cost estimates on these programmes show annual budgets four times the current levels or twice the annual budgets needed for the Post-Apollo programme. When the longer timescale is taken into account the total programme cost is four times as great and, even then, the overall result is not as effective in terms of

reaching the 2050 target.

If we do not undertake such programmes and leave space alone with only modest initiatives (e.g., only undertake the Space Station programme) for another 10 or 20 years, the task of reaching the 2050 target becomes massive. There is so little time that, effectively, all the growth would need to be government-funded and the total programme would cost maybe 15 times that of the Post-Apollo programme. This will mean annual Western world civilian space budgets 10 times current levels. That is in the order of $200 billion a year in late 1980's dollars, with money needed to be found at the time when the decline of the global economic and social infrastructure has already started.

Not only are such levels of expenditure unlikely, there would also be a technical problem with moving at such a fast pace. Each infrastructure element needs to be introduced before the other systems it relies upon are properly verified and operational. Thus the budgets, the pace, methods of technical progress, and the probable cost in human lives, will make the exercise seem more like a war than building an infrastructure.

It is imperative to act now. There are many good short-term reasons why investment in space is important and these alone could be used to justify the development of a space infrastructure. However, we should not lose sight of the long-term goal of expanding our civilisation into the Solar System, as this will be the only viable way, eventually, of maintaining that civilisation. We face a choice of the type future that we leave to posterity; a stone age or a space age. If it is to be a space age there is a need to act now with much greater vigour than is currently being shown.

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2. "The Resourceful Earth; A Response to Global 2000" by Julian Simon and Herman Kahn, Blackwells 1984 ISBN 0631 13467 0.
3. J. Peter Vajk's comments are quoted on page 97 of "Space Colonies" Edited by Steward Brand Penguin 1977 ISBN 0 14 00.4805 7.
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6. A description of this model can be found in: "Citizens of the Sky" by Robert C. Parkinson 2100 Ltd, ISBN 0 9512989 0 9.
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Near-Earth Asteroids Observed

International cooperation plays a vital role in the observation of near-Earth asteroids and the determination of their orbits. When an orbit becomes established, it may be possible to relate old sightings to the same asteroid body. The feasibility of spacecraft rendezvous missions to asteroids is currently being assessed on the basis of available orbital data.

In 1988, 390 new asteroids were discovered during the Planet-Crossing Asteroid Survey's (PCAS) monthly observing runs at Palomar Observatory. Of particular interest are three near-Earth asteroids, Apollo 1988 EG and two Amors, 1987 QB and 1988 PA. To date, 1988 EG and 1988 PA are the only near-Earth asteroids found worldwide although the search activity for those rare objects has increased substantially. In conjunction with the International Near-Earth Asteroid Search (INAS) program - coordinated from JPL - the Bulgarian wing of the project discovered Apollo asteroid 1987 SB. Nearly concurrent, confirming observations were provided from Palomar. In addition, about 40 high-inclination objects were found: Mars-cross asteroids and inner-belt-region objects, the Hungarians and Phocaeas. Since 1982, the known number of those intriguing objects, which seem to be precursors to the near-Earth asteroids and probably number among them a few degassed comets, has more than doubled.

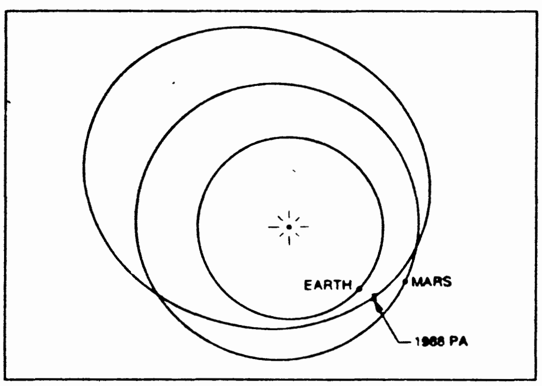
Of special note is the number of recoveries of PCAS-discovered asteroids. Amor asteroid 1982 XB was recovered in November 1987. Refined observations led to the recovery of tiny, 350-m asteroid by radar from Arecibo. These radar results will help ensure the future acquisition of 1982 XB over the next 25 years. Amor 1982 XB has been identified as a prime mission candidate because of its low delta v (5.2 km/s) requirement for rendezvous. Thirteen opportunities between 1990 and 2010 have been found.

The most favourable are in 1992, 1995, 1997, and 2007. It has now been officially numbered 3757. Tow other very faint near-Earth asteroids, 1986 LA and 1986 PA, have been recovered. They are two of the smallest objects of the some 110 known near-Earth asteroids. Amor, 1985 D02, was recovered in August 1988. It brightens to magnitude 13 in September so that it offers an excellent opportunity for extensive physical observations. Unique Mars-crosser (3800) 1984 AB, and strong Mars-crosser (3737) 1983 PA were also recovered and numbered this year.

Earth-crossing Apollo 1988 EG was discovered March 12, 1988, after it had already made its closest approach to Earth on February 26 at 0.040 AU (6 million km). It was then already moving away from Earth. Apollo 1988 EG travels in an orbit that takes it inside the orbit of Venus (perihelion distance of 0.64 AU) to beyond the orbit of Mars (aphelion distance of 1.90 AU). The asteroid has an inclination of 3.5 deg to the ecliptic and an orbital period of 1.4 years. The circumstances of discovery were fortuitous, since the small body makes an approach to Earth is favourable for observation only once in 10 years. 1988 EG has been observed over a 2-month period, which ensures the asteroid's recovery with the use of large telescopes in mid-1990 and the spring of 1991.

Preliminary assessment suggests that, with its small orbit, modest eccentricity, and a low inclination, they recently discovered Amor asteroid 1988 PA may rank among the first dozen or so further spacecraft mission candidates with minimum delta V requirements.

From a NASA/JPL 1988 report on the Asteroid Search Program.



Orbital plot of Amor asteroid 1988 PA at discovery on August 9, 1988. A possible candidate for spacecraft rendezvous.

Space Travel: Fiction and Reality

In his Pulitzer Prize winning *book ...the Heavens and the Earth,* Walter McDougall suggested that all science fiction "was a form of cultural anticipation." [1]. He begins *...the Heavens and the Earth:* "The great pioneers of modern rocketry-Tsiolkovsky, Goddard, Oberth, and their successors Korolev, von Braun, and others, were not inspired primarily by academic or professional interest, financial ambitions, or even patriotic duty, but by the dream of space flight. To a man they read the fantasies of Jules Verne, H.G. Wells, and their imitators. The rocket, for them, was only a means to an end" [2].

By Dr. L. Suid

Tsiolkovsky saw science fiction as giving direction to his work: "For a long time, I thought of the rocket as everybody else did - just as a means of diversion and of petty everyday uses. I do not remember exactly what prompted me to make calculations of its motions. Probably the first seeds of the idea were sown by that great fantastic author Jules Verne. He directed my thoughts along certain channels, then came a desire, and after that, the work of the mind" [3].

For his part, Robert Goddard believed that he had probably inherited his "innate interest" in mechanical things from "a number of ancestors who were machinists." Nevertheless, the future rocket scientist attributed the motivation for exploiting his aptitude to reading science fiction stories, particularly H.G. Wells's "War of the Worlds." According to Goddard, the stories "gripped my imagination tremendously. Wells's wonderful true psychology made the things very vivid, and possible ways and means of accomplishing the physical marvels set forth kept me busy thinking" [4].

In writing to Wells in 1932, Goddard described how the images in War of the Worlds interacted with his thought processes: "I was sixteen years old and the new viewpoints of scientific applications, as well as the compelling realism of the thing, made a deep impression. The spell was complete about a year afterward and I decided that what might conservatively be called 'high-altitude research' was the most fascinating problem in existence." This inspiration had led Goddard to the study of physics and of space flight. He told Wells that he did not know how long he would be able to work on the problem, but he hoped, "... as long as I live. There can be no thought of finishing, for 'aiming at the stars,' both literally and figuratively is a problem to occupy generations, so that no matter how much progress one makes, there is always the thrill of just beginning" [5].

In contrast to Tsiolkovsky and Goddard, Hermann Oberth contributed not only to the development of space science but also experienced the thrill of seeing man land on the Moon. Oberth's broad interest in mechanical things that moved quickly received an early focus from science fiction: "At the age of eleven, I received from my mother as a gift the famous books, From the Earth to the Moon and Travel to the Moon by Jules Verne, which I read at least five or six times and, finally, knew by heart" [6].

While the stories of man's first journey to the Moon stirred his imagination, Oberth recognised "that shooting a missile out of a giant gun with the travellers inside, as Verne imagined for space flight, would not work. Even if it would have been technically feasible to produce such a gun, the travellers inside the missile would have been crushed without pity by the enormous acceleration." Although he had not yet acquired a significant knowledge of mathematics, Oberth was able to calculate that Verne had come close in his writings to the actual escape velocity which a missile would need to leave Earth's gravitational field. Since a gun would not serve as a missile launcher, Oberth began to think of other solutions of giving a vehicle the necessary speed [7].

His early musings did not provide answers to the problem. Nevertheless, he continued to draw on Verne's imaginative writings: "From the very beginning in these childhood projects, I always had in mind the rockets designed by Jules Verne for braking the gravitation pull toward the Moon and for changing direction of travel in space. I gradually realized that reaction propulsion actually offered the only means of achieving space travel and that giant rockets would be used as spaceships of the future, even if they lost in appearance any resemblance to our fireworks, as in the case with the electric spaceship designed by myself" [8].

Ultimately in 1923, Oberth published The Rocket into the Interplanetary Space, in which he set out all he had to say about transporting human beings into space using liquid rockets. The book established his eminence in the field and his reputation grew during the 1920's as he continued to write and teach. As a result of his reputation, the German film director Fritz Lang asked him to serve as the technical adviser during the production of his 1929 film A Girl in the Moon. Although Oberth's efforts to promote the film by launching a liquid fuelled rocket failed, the film inspired many young Germans, including Werhner von Braun whose early interest in rockets had also come from Jules Verne.

Like them, Oberth worked on the German wartime rocket programmes and joined von Braun in Huntsville later during the development of the rockets that were to put the first men on the Moon. In Oberth, then, the transformation of the dream of manned space flight into reality came full circle. Inspired by Verne, Oberth provided the scientific basis that turned imagination into hardware and, unlike most of the early visionaries, he was at Cape Kennedy to watch Apollo 11 take off for the Moon.

On his part, however, Walter McDougall argues that scientists and rocket engineers made no contribution to the policy decisions that led to the Apollo programme:

"Of all those who contributed to the Moon decision, the ones farthest in the background were the engineers of Langley, Goddard and Marshall, many of whom devoted their lives to space flight, designing dreams. Their reports and studies were necessary buttresses to the political arguments: they had to persuade that the thing could be done. Otherwise, they were absent. Some of their visionary talk about exploration and destiny found place in political speeches but their efforts to stretch the minds and hearts of their fellows, to sow wonder for its own sake, got lost in their very adoption by the technocratic state. [9].

President John Kennedy did not go before Congress on May 25, 1961 to request money for research and

development of rockets so that the US could someday have a space programme. In fact, he came to Capitol Hill to propose specifically that the US turn man's dream of going to the Moon into reality. He could propose this only because the space scientists and rocket engineers, the Tsiokovskys, Goddards, Oberths, and von Brauns, inspired by Verne, Wells, Lang and their cultural successors, had already developed and were prepared to build the vehicles that could go to the Moon "in this decade."

Simply put, the imagination of manned space flight, at least since Jules Verne, had convinced the vast majority of the American people that a trip to the Moon would occur sooner or later. Without this belief, people would undoubtedly have laughed President Kennedy off the podium for proposing such an absurd idea of going to the Moon.

What relationship did the ideas about man's first trip to another heavenly body have to the reality of the Apollo Moon programme?

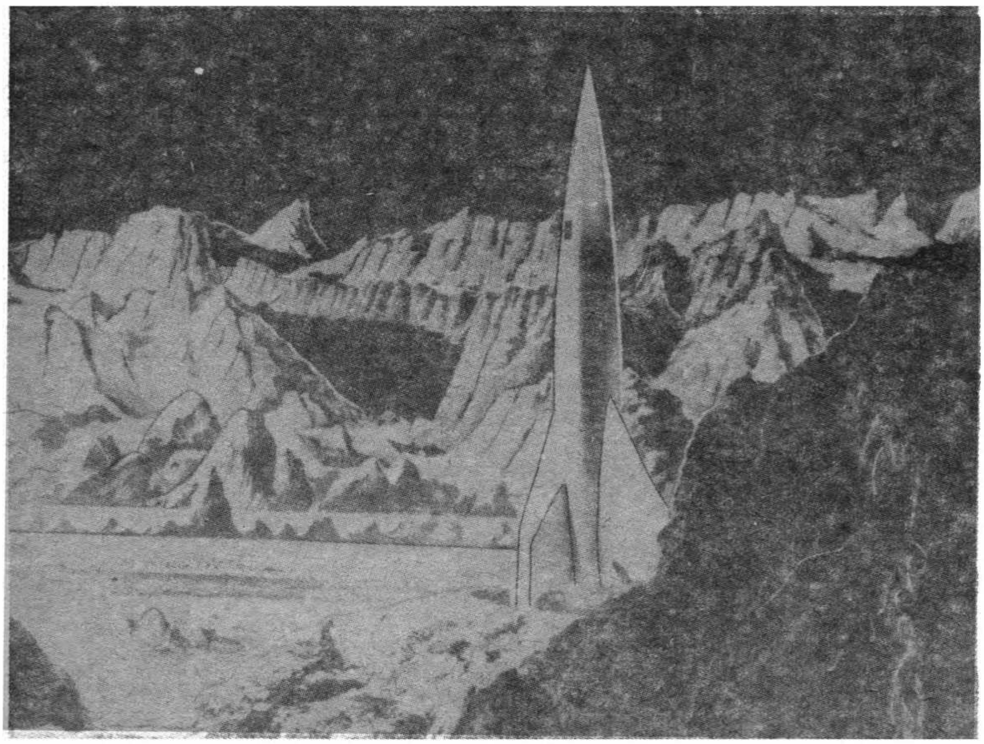
H.G. Wells may have made a deep impression on Robert Goddard but, nonetheless, his images of space travel remain little more than fantasy, ie., Martians coming to Earth in firey missiles and man going to the Moon propelled by an anti-gravity element attached to the outside of the space capsule.

In contrast, Jules Verne drew upon the best available scientific information, thus gaining credibility from scientists, and the general public. To be sure, some implausibilities exist in his stories, e.g., the method he used to launch his space vehicle. Consequently, despite the occasional flaws, Verne's work introduced science to the masses in a form they could understand.

Hermann Oberth

In From Earth to the Moon and Around the Moon Verne's travellers reach Moonspace and continue their voyage back to Earth, ultimately landing in the Pacific where an American warship rescues the astronauts. Verne did not have his crew actually land on the Moon, probably because he could conceive of no way to duplicate his launching cannon there.

A scene from: Destination Moon.



Verne's ideas had a profound influence on readers, in addition to the early pioneers of space flight. Dr. Melvin Calvin, the 1961 Nobel Prize winner for chemistry and a leading planner and experimenter in the search for extraterrestrial life recalled that as a boy, he read Wells and Verne from cover to cover: "I used to live those stories. I can remember actually departing from this world for the course of the hours or days that it took to read one of the books. I was not a part of this world - I was a part of what I was reading" [11].

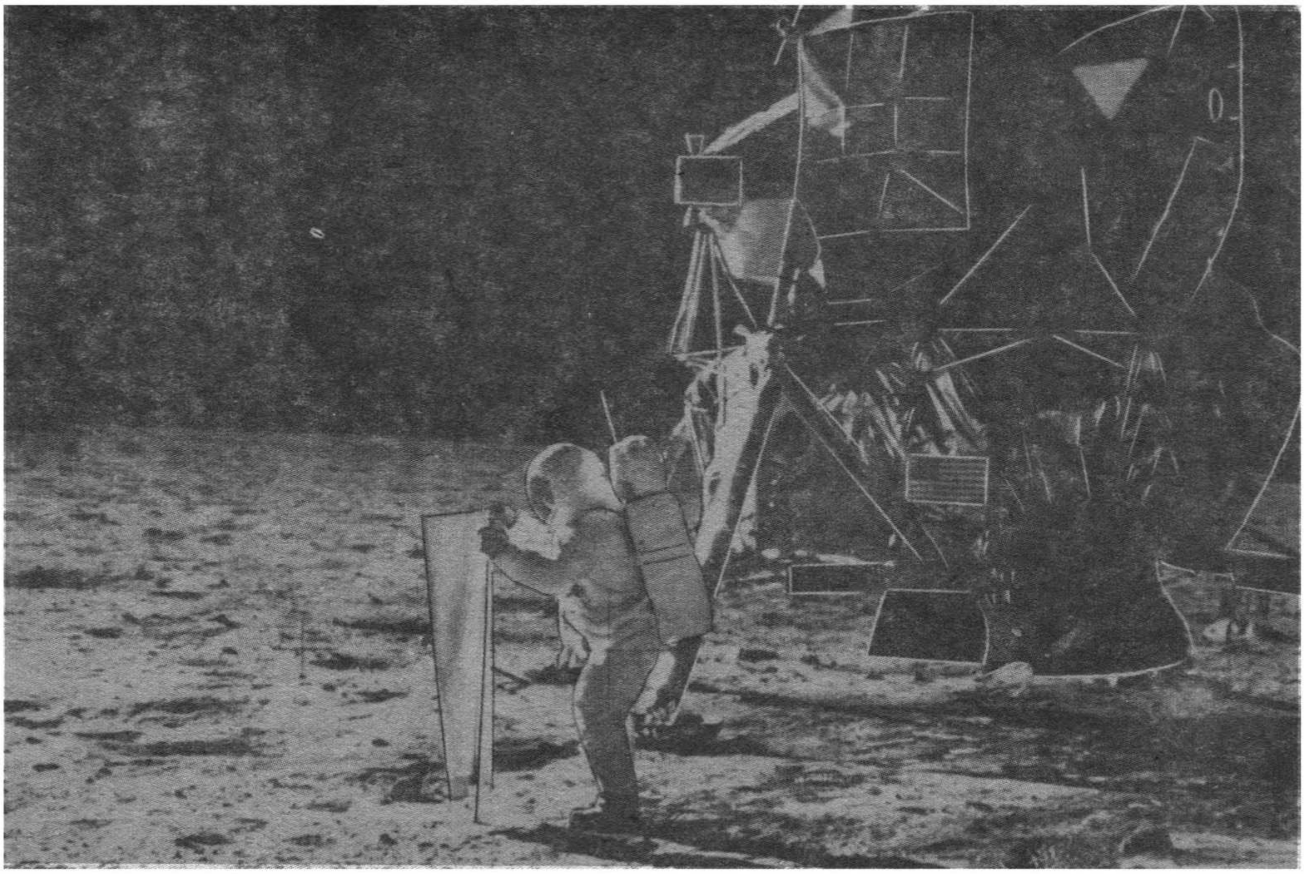
Even Neil Armstrong, who has claimed that he could not "provide any information regarding science fiction films that would be of any value, as I have no expertise in that field," once cited Verne. In a televised news conference on his way back from the Moon, the first man to walk on the Moon told the world, "A hundred years ago, Jules Verne wrote a book about a voyage to the Moon. His spaceship Columbia [sic], took off from Florida and landed in the Pacific Ocean, after completing a trip to the Moon. It seems appropriate to us to share with you some of the reflections of the crew as the modern day Columbia completes its rendezvous with the planet Earth and the same Pacific tomorrow" [11].

Turning to the first cinematic representation of manned space flight in the 1903 French movie A Voyage to the Moon, the filmmaker, George Meleis drew his inspiration from Verne's two books. While also committed to scientific accuracy, Meleis changed the literary images. Unlike Verne, who had postulated a barren and lifeless Moon, Meleis, populated it with strange, fairy tale-like creatures.

This allowed the director to include a major battle between the Earthmen and the residents of the Moon. More important, having landed his men on the lunar surface, scoring a direct hit in the eye of the man in the Moon in the process, Meleis did solve the problem of getting the space travellers back to Earth.

Their capsule conveniently falls off the Moon and plummets into the Pacific Ocean and is rescued by a warship. Meleis created one enduring image that proved prophetic: his crew received a tumultuous welcome, very similar to what both the cosmonauts and astronauts were to endure.

A Voyage to the Moon had a great impact. The landing itself, actually portrayed twice from different perspectives, has become something of an icon of science fiction and remains almost as familiar as Neil Armstrong's first step on the Moon. According to



In July 1969 the fiction became a reality when Neil Armstrong and Buzz Aldrin became the first men on the Moon. Buzz Aldrin is pictured here assembling an experiment. *NASA*

the film director's granddaughter and great granddaughter, the film became the most popular of all the director's 500 plus movies. Some audiences even came to believe the film portrayed an actual trip to the Moon and became very worried, not unlike what happened with Orson Welles "War of the World" only 50 years ago [12].

Fritz Lang's 1929 A Girl in the Moon did not provide any single image that has endured as long as Meleis's lunar landing. While the film has its own moments of implausibility, the visualisation of the rocket hardware does not look all that outdated even today, undoubtedly due to the technical advice of Herman Oberth.

To be sure, Oberth could not dissuade Lang from having his Moon contain a breathable atmosphere. The director argued that he would not film his actors in "diving" suits even though Oberth pointed out that the Moon had no oxygen. He even cited an authority to justify his portrayal - H.G. Wells, who provided his Moon with breathable air.

Giving some lipservice to plausibility, however, Lang did have the first man on the Moon disembark from the lunar lander in a space suit and test for an atmosphere, by lighting a match. When it burns, the scientist joyously throws off his protective outfit and Lang has his freedom to film the actors cavorting in normal clothing.

On the other hand, the director did use Oberth's concept of a multi-stage rocket as the vehicle of choice. Unlike fictional trips before and after A Girl in the Moon, Lang created an ambience of scientific exploration by including a reference to an unmanned surveyor satellite which sends back photographs of the Moon to prepare for the manned trip.

Like Verne and Meleis, Lang included the standard debate between groups of scientists over the possibility of manned space flight to the Moon. In his case, the scientist who proposed the trip in order to mine gold is discredited and the actual flight occurs many years later - with the now-old scientist aboard.

Lang, with Oberth's help, created a Moon journey not too different from the ultimate trip. Unique to science fiction, the movie anticipates the future by portraying the vehicle as a multi-stage rocket assembled in a building not unlike the Vehicle Assembly Building at the Kennedy Space Center. The completed rocket is then towed out to the launch pad which proves to be under water. According to the title, this technique is necessary because the rocket is too light to support itself during its launch.

Ironically, NASA seriously considered using a barge as the launch pad for Apollo because of the very weight of the Saturn rocket.

The actual launch, which takes place at night, probably to save money on special effects, anticipates the huge gathering of spectators and media types, If nothing else, the scene suggests that science-fiction writers and filmmakers appreciated the significance of the first trip to the Moon.

During the flight, Lang portrayed weightlessness aboard the rocket, albeit for dramatic effect when convenient. The crew moves around, sometimes normally, sometimes by floating, and sometimes by hooking their feet through stirrups attached to the walls of their ship. But Lang does not concern himself with maintaining the effect on a consistent basis since the movie remains nothing more than a romance and melodrama set on the Moon.

Overall, the hardware is surprisingly believable. The portrayal of the rocket stage separations is not all that different from the simulation which the TV networks used during the Apollo missions and the rocket lands

on its tail.

What A Girl in the Moon and most similar stories from Meilis onward lacked was any portrayal of a series of flights, each building on the experiences of the previous effort in preparation for the final assault on the lunar surface.

When asked about the significance of the lunar landing, Wernher von Braun observed: "Oh, I would say about with the events of aquatic life crawling on the land for the first time." After the successful touch down of the lunar lander, the rocket engineer went even further: "I think the ability of man to walk and actually live on other worlds has virtually assured mankind immortality" [12].

Put another way, the landing of the Eagle on the lunar surface represented the culmination of man's cultural dreams of manned space flight and of his scientific and technological creativity.

The success of his book, Rocketship Galileo, and the images of manned space flight which he created provided Robert Heinlein with an entree to Hollywood and, working with George Pal, he wrote the screenplay for Destination Moon, the first postwar and first colour movie about a lunar expedition.

Unlike his book, the movie portrays a highly plausible expedition. The "standard" debate focuses not so much on whether man can or should go to the Moon, but whether the government or private industry should undertake the project. Given Heinlein's political philosophy, private industry wins out. We are told that the government does nothing except in crisis so industry must act to protect the nation's interests.

Besides failing to predict that a lunar landing would require the entire resources of the nation, filmmakers did not foresee the explosive growth of television and how the medium would be able to capture virtually every moment of the lunar flight. Nor did they recognize that computers would become indispensable for the journey.

Moreover, Pal and Heinlein did choose to return to the pre-Girl in the Moon, single stage, direct ascent rocket, now atomic powered, rather than accept Oberth's multi-stage rocket. Like a good action, adventure movie, the crew is composed of a cross-section of Americans and, in the tradition of previous science fiction movie, the men do not undertake any special training for their flight.

Nevertheless, the filmmakers did have a strong commitment to making Destination Moon as scientifically accurate as possible within the knowledge then available. Consequently, for the most part, the film has the aura of a documentary, which, even today, does not seem too dated.

During the flight, the crew functions in a weightless environment at all times. The rocket lands on its tail and, while on the Moon, the astronauts perform their tasks as if they were actually under the influence of one-sixth Earth gravity. More important, they seem genuinely awed by their accomplishment and their comments are not too different from those of the men who walked on the Moon less than twenty years later. While the film's climax resembles a melodrama, the viewer has the impression that the ship will return to Earth safely.

The hardware of the Mercury, Gemini, and Apollo programmes started to influence what filmmakers began to create.

Whatever dramatic and scientific shortcomings Destination Moon had, it did launch the Golden Age of Science Fiction that existed during the 1950's. Ironically, the movie lost the race to the nation's theatre screens for Rocketship X-M made in ten days, appeared a few weeks before Pal's movie.

Originally intended to portray man's first voyage to the Moon, the producers changed the destination to Mars to avoid a possible lawsuit from Pal. While lacking some of the scientific accuracy and production values of Destination Moon, Rocketship X-M contains many of the same images as its more expensive companion, and it offered the same message - man would shortly break his Earth bonds, fly to other heavenly bodies, and face new challenges.

As is often the case with literature or film, most of the stories which followed the initial groundbreaking stories remained little more than pale imitations of the originals. One of the worst of these, and perhaps one of the worst movies ever Cat Women on the Moon, uses a generic, single stage, direct ascent rocket to take its crew to the Moon.

Budget considerations or, more likely, a disinterest in hardware or plausibility take over. The spaceship's cabin looks as if shot in some office furnished with a "government-issue" desk and standard, commercial radio microphone for communication with Earth. The producers did not bother to simulate weightlessness, even occasionally, as Fritz Lang had done. Though they did follow his approach to the environment of the lunar surface by providing it with a breathable atmosphere. Of course, the film was not aimed at a knowledgeable audience but to young males who might find the "catwomen" appealing.

Whether bad or good, however, the science fiction literature and movies up to Sputnik and the beginning of manned space flight may well have influenced at least one element of the population, the rocket engineers. Except for Hermann Oberth, the men most directly involved in finding ways to transform the dream of manned spaceflight into reality seemed committed to the direct ascent approach of putting man on the Moon.

In discussing his efforts to sell to NASA engineers and scientists the "rendezvous in orbit" approach, John Houbolt recalled that he simply could not interest anyone in the method. When asked if this resulted from images in books and movies having influenced people into thinking only in terms of a direct ascent approach to a lunar landing, Houbolt replied that it seemed as good an explanation as any [13].

In any case, once President Kennedy issued his call to the US to place a man on the Moon before the end of the 1960's, the fiction and reality of manned spaceflight began to merge. The hardware of the Mercury, Gemini, and Apollo programmes started to influence what filmmakers began to create. However, NASA never really came to terms with how to use these images to further its programmes. It tried to spread its message through the news media and in educational programmes but, in the end, did not trust the reality of its space missions to generate sufficient excitement to produce on-going support within the US Congress and among the American people.

As a result, the NASA Public Affairs Office cooperated with Hollywood in the making of feature films purportedly to show the American space programme in operation. Unfortunately, the major releases did not contain stories that in any way would engender support for its projects.

Countdown portrayed NASA's internal operations filled with policy disagreements, backbiting among officials and astronauts, and a decision to launch a suicide mission to the Moon in the hopes of beating the Soviet Union to a lunar landing. As the title suggests, Marooned told the story of a failed American orbital mission, the death of one astronaut while the crew waits for an American rescue rocket and their ultimate rescue by a Russian cosmonaut. Finally, Capricorn One details how the head of NASA stages a fake landing on Mars.

The success of the Apollo programme itself made all previous sto-

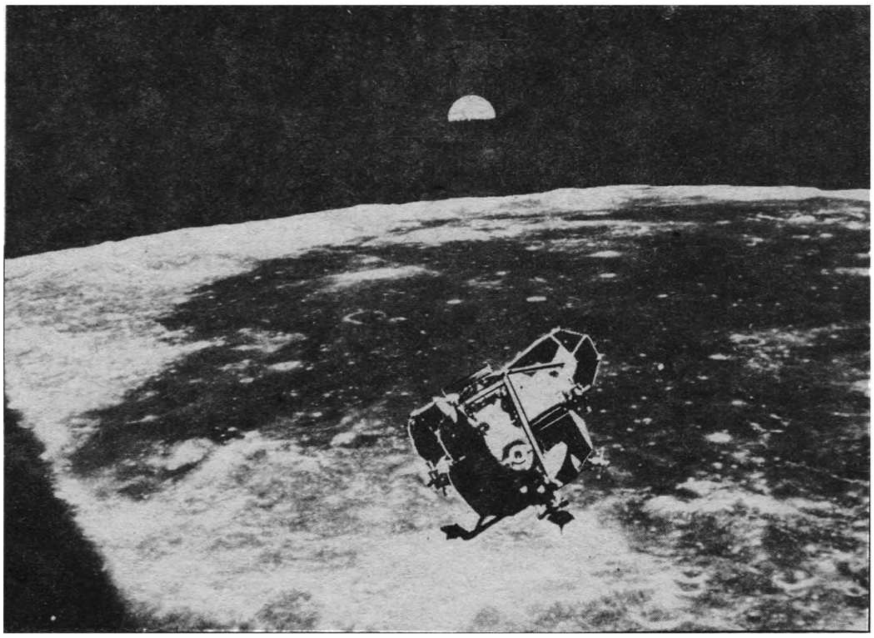
ries about the first men on the Moon obsolete. 2001 stands as a link between the science fiction past, the contemporary reality of the Moon becoming known to man and the model for the subsequent space epics that appeared during the 1970's. In making the movie, Arthur Clarke and Stanley Kubrick faced the possibility of having the discoveries of the Apollo programme render their portrayal of the Moon out-of-date. The fact that the movie's images of the Moon still seem real speaks to the success of the filmmakers.

Except for the fleeting scenes on the Moon in 2001, no significant portrayals of life on the Moon existed for NASA to use in helping sell Congress or the American people on the need to establish permanent lunar colonies. So, with the Vietnam War having drained funding from NASA and created antipathy to future, large scale government programmes like the Apollo Project, America's space programme entered into limbo during the 1970's.

To science fiction writers and filmmakers, the Moon no longer became the focus of attention. The shuttle became the vehicle of choice for travel in near space. However, for the most part, images of manned space flight from Star Trek to Star Wars and the continuation of Isaac Asimov's Foundation series, became those of exploration into the outer reaches of the Universe, "where no man has gone before."

Whether these images will ultimately have an impact on America's space programme remains to be seen. Jesco von Puttkamer, NASA's Programme Manager for Long-Range Planning and a technical advisor to Star Trek: the Movie, believed film provided NASA with "a legitimate way of beating our drum" and "by showing deeds rather than words, demonstrate what we are standing for." The film, he said, gave NASA " a chance of being depicted in a positive way where we can show, hey, we made it 200 years from now. And that the name NASA survives and is being used as a plug" [14].

Beyond that possibility, what impact has science fiction had on America's space programme? In his chapter on the decision to go to the Moon, McDougall says, "When the Soviets weighed in by orbiting Gagarin, and the Shepherd flight confirmed NASA's contention that the mission was feasible, all barriers came down. All, that is, except cost, and that, too, was less important in the new White House. We will probably never know precisely what was in Kennedy's mind when he decided that Americans should go to the Moon. What may have tipped the balance for him and for many was the spinal chill attending the thought of leaving the Moon to the Soviets. Perhaps Apollo could not be justified, but, by God, we could not **not** do it" [16].



The Apollo 11 Lunar Module, Eagle, returns to the Command Module after completing work on the surface.
NASA

John F. Kennedy did not apparently read science fiction and so did not see his decision to embark on a lunar landing as fulfilment of a childhood dream. He saw space as a new arena to explore in much the same way as Columbus saw the oceans of Earth as avenues to the unknown. In some measure then, by launching the Apollo Programme, Kennedy saw himself in relation to NASA as Isabella to Columbus, with a successful landing on the Moon ensuring his place in history.

Clearly, the President could not go before Congress and request $25 billion to become immortal. Instead, he used other arguments the need to beat the Soviets and so demonstrate the continued American technological superiority over the USSR; the gains for science and technology regardless of the outside competition; and the "focus argument", which used the Apollo programme to push the entire US space effort [16].

Likewise, while citing the space race and the need to demonstrate leadership to the World, Bobby Kennedy recalled that the President compared the importance of space to the exploration of the US by Lewis and Clarke, concluding, "I think that made a profound impression on him" [17].

As with most significant events in history, the decision to go to the Moon can only be understood as the result of the merging of many ideas and influences. While not the only one, popular cultural expressions of science fiction clearly had an impact on the American space programme, in the politics of space and, through scientists and engineers, on the development of the technology of space flight.

If nothing else, science fiction created an interest in space among the majority of the American people and convinced them that going to the Moon would occur one day. In turn, President Kennedy, consciously or subconsciously, drew on the cultural images of adventure and exploration within science fiction to sell the Moon programme to the nation.

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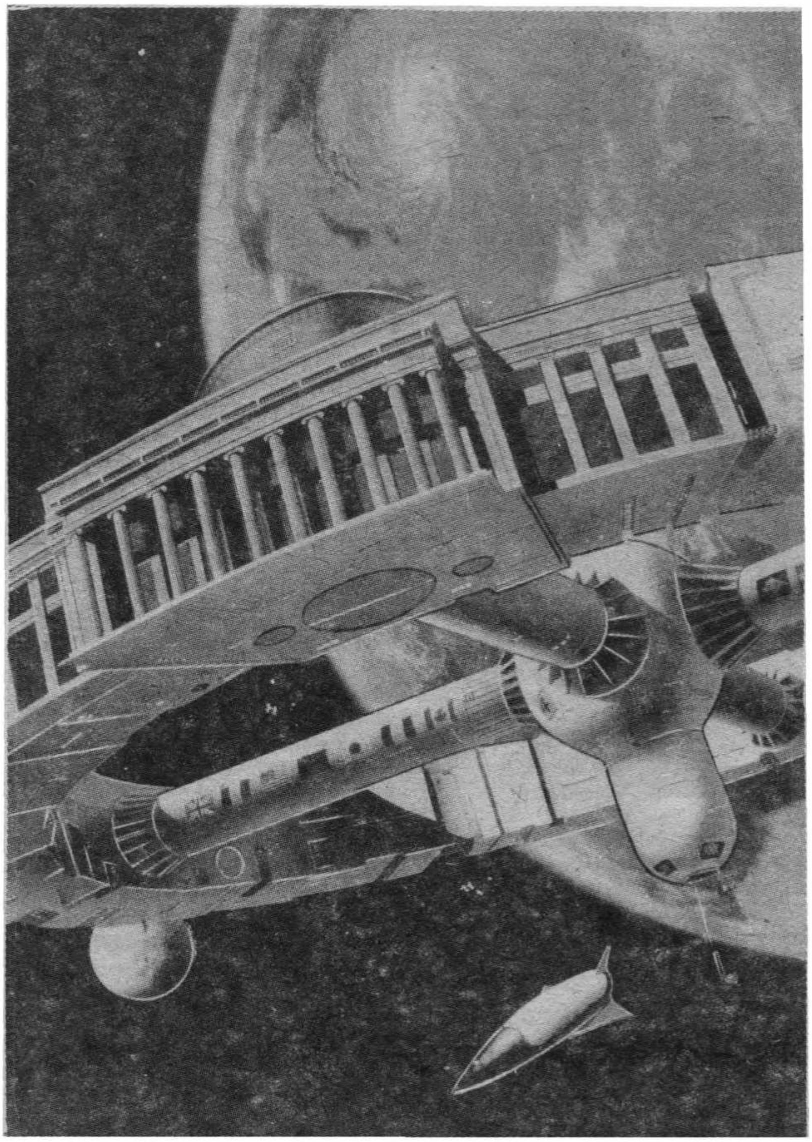
INTERNATIONAL SPACE UNIVERSITY®
HEADING TOWARD ORBIT



The International Space University (ISU) was founded in April 1987 at a conference held at the Massachusetts Institute of Technology (MIT). The ISU co-founders—Peter H. Diamandis, Todd B Hawley and Robert D. Richards—forwarded a concept in space education which has captured the imagination and support of the world's space community. With the involvement of academia, governments and industry from numerous nations, ISU will expand into a full-year academic program and permanent campus locations following 1992, the International Space Year. "Clearly the ISU plans are quite ambitious, but the concept has won over many of its early doubters," notes Mr. Ian W. Pryke, head of the European Space Agency's Washington Office. "The momentum and success the ISU has built is why I am proud to serve as its Chairman of the Board "

continued on next page

The Birth of a 21st Century Institution

It is my pleasure to write a few words on behalf of an organisation I helped to start and which is close to my heart: the International Space University. ISU is an outstanding new institution dedicated to identifying, unifying and educating the world's best young professionals and outstanding graduate students involved in space-related studies from architecture and engineering to life sciences and business. Through its academic programmes, ISU is cultivating a new generation of leaders dedicated to the peaceful use of outer space.

After the phenomenal success of its inaugural summer session at MIT, ISU is setting its sights on the establishment of a permanent central campus during International Space Year (1992). In the next few years, ISU will expand to include multiple campuses at centres of excellence around the world—linked together via satellite, sharing an electronic library and data bases, offering live lecture transmissions and implementing modern technologies—to enhance cooperative research and development of space. One day soon, perhaps by 2001, ISU will have a campus where it is destined to be: *in orbit!*

ISU is doing more to promote and guarantee the peaceful and permanent development of space than any other institution I know. I have been a sponsor of ISU since its founding, and I hope that you will be able to join with me in supporting this unique educational endeavour.

Sincerely,

Arthur C Clarke

Arthur C. Clarke is the author of* 2001: A Space Odyssey. *He serves on the ISU Board of Advisors and is the Chancellor of the University of Moratuwa, Sri Lanka.

ISU Gains Momentum

continued from first page

The inaugural summer session of ISU was held at MIT in 1988, and brought together 104 graduate-level students and young professionals from 21 nations. ISU's first academic program provided an innovative package: a nine-week summer session involving a broad curriculum, state-of-the-art equipment and labs, design projects, and an international faculty and student body. During the program, all students participated in a total of 240 hours of lectures encompassing eight disciplines. The ISU academic program was led by a core faculty of 30, enhanced by more than 70 visiting lecturers representing today's leaders in the international space community.

ISU operates from its Executive Office in Boston, Massachusetts, USA, which is headed by Peter H. Diamandis and Todd B. Hawley

The 1989 summer session will take place at Université Louis Pasteur in Strasbourg, France from 30 June to 31 August. The structure of ISU'89 evolved from the ISU program offered at MIT in 1988: a nine-week session of interdisciplinary lectures and design project activities, and eight academic disciplines: Space Architecture, Space Business and Management, Space Engineering, Space Life Sciences, Space Policy and Law, Space Resources and Manufacturing, Satellite Applications, and Space Physical Sciences.

In conjunction with summer sessions, ISU is pursuing the goal of establishing a permanent campus during International Space Year (1992). Following the 1992 International Space Year, the ISU plan is to open first its Central Campus, later adding Satellite Campuses for advanced research and study in ISU disciplines in existing centers of excellence located around the world. At the permanent campus, worldwide satellite broadcasting of lectures will be routine; computer conferencing and networking, electronic library and database access will be used to link together the varied elements of ISU.

An ISU Founders Association has been launched to help establish ISU's permanent campus and to assure the continuation of this global experience for future generations. Founders Association members will help finance the planning, analyses, needs assessments, design and construction of permanent ISU facilities. Members of the Founders Association are determined to prepare a complete development plan for International Space University, and secure a sound financial base for its implementation.

The process by which humanity develops and explores space has changed in many critical ways over the last 30 years. Space is no longer the realm of the economic superpowers, nor is it a domain limited exclusively to scientists and engineers. Today space development takes place in an international, interdisciplinary arena. ISU seeks to provide a general understanding of technical and non-technical areas important to space development, and to gather together the leaders of tomorrow, allowing them to discuss common goals, motivations and ideas. The International Space University invites visionary men and women of all nations to join and support this critical mission.

ISU Captures the

The International Space University mission is to offer educational programs which are of relevance to today's space industry. From its inception in 1987, ISU has fostered increasing levels of support from a diverse international roster of corporations and agencies whose leaders recognize the value and impact of the programs offered at ISU.

"In this era of expanding civil space programs, there is an ever-growing interest and need in our industry to identify and train young people who can operate successfully in an international commercial environment," notes John McLucas, Chairman of QuesTech, Inc. "The ISU seeks to satisfy the emerging training needs of the aerospace industry."

ISU has pioneered a unique education niche which has proved as relevant to aerospace firms in North America, Japan

The Power of ISU

One hundred and four rare individuals now have friends and professional colleagues in 21 different countries of the world. These are the students of the first graduating class of International Space University. The ISU alumni form a cadre of dedicated space professionals who will provide the leadership to launch humankind into space.

To illustrate the effect the "ISU Experience" has already had, a sampling of alumni perspectives is presented here:

- "This has been the most important educational experience of my life," said Mark Matossian, the first alumnus to obtain graduate course credit for his work at ISU'88, and now a staff scientist at SAIC. "Never have I been asked to push myself as far and as fast as I did at ISU this summer."

- "During ISU I made contact with individuals from many space-related corporations—many of them I have remained in frequent contact with, this will help to create new opportunities for all of us,"

Interest of Space Industry Leaders

Space industry leaders from over 20 nations have endorsed ISU.



Yasuhiro Kuroda ***SHIMIZU*** — ***Claude Goumy*** ***MATRA SPACE*** — ***Dean Burch*** ***INTELSAT***

and Europe as it has to telecommunications corporations in Africa and Australia. Proof of this relevance may be noted in Japan's increased participation in ISU in 1989, which will include at least 17 students — an increase from five participants in the 1988 program at MIT

"We wish to promote the ISU program among Japanese corporations because we believe that space development will require professionals who have an international perspective and who will succeed in the increasingly cooperative world space industry," explains Dr. Yasuhiro Kuroda, Senior Advisor of Shimizu's Space Project Office, Japan's ISU Liaison since 1987

"In Europe, the multi-national nature of many space activities makes the International Space University program particularly valuable," remarks Claude Goumy, General Manager of MATRA SPACE, which is sponsoring students and curriculum development for the ISU'89 program in Strasbourg, France. "I believe that the international educational experience of the ISU will have very great long-term benefits in our firm, our nation and the world."

At the INTELSAT Organization, 115 nations own and operate an expanding international satellite communications system which is often referred to as one of the best examples of successful multi-national space cooperation. "It has been our pleasure to support [the ISU] enterprise," notes Dean Burch, the INTELSAT Director General and a member of ISU's Board of Advisors. "It is extremely pleasing to see how successful the ISU program has become in such a short period of time."

Networking

says Akiyoshi Kabe of Mitsubishi Electric Corporation. "I know I am only a fax or a phone call away from hundreds of people — space experts, astronauts and CEOs—who are not only my colleagues but also my friends"

- ISU Alumna Marina Aguiar of Brazil adds "ISU gave me an excellent understanding of how my work in materials science can be used in the development of space, and the multicultural environment helped to broaden my view of the world."

- Vadim Vlasov, a Soviet alumnus very active in US-USSR relations, noted: "I was impressed with the expertise, diversity and enthusiasm of the ISU faculty. It was extremely interesting for me to hear the perspectives of faculty from 14 nations."

- "Immediately following ISU, I was offered a job by the Canadian Astronaut Program. As one of my first assignments I was sent to the Soviet Union to discuss experimental procedures and logistics for two Canadian experiments to fly on Biocosmos 1989," says Canadian Alumna Kristiina Valter. "My friendship and experience with my 12 Soviet ISU colleagues was invaluable in this trip to the USSR."

ISU'88 graduates Mark Matossian (USA), Akiyoshi Kabe (Japan) and Kristiina Valter (Canada)

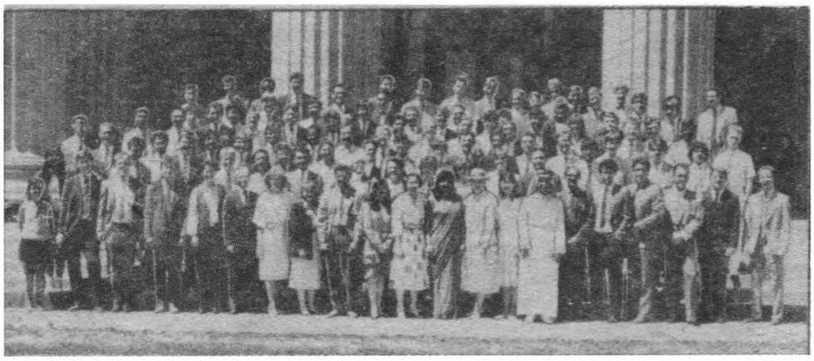
The shaded regions on this world map represent those nations which sent their top students to ISU'88

- Russel Hannigan is the youngest member of the British Aerospace Hotol research and development group. He notes, "My experience at ISU and the design project activities allowed me to work with a culturally diverse group of people, and also gave me the opportunity to gain knowledge which is valuable to my work at British Aerospace."

- "When I returned from ISU I received a very important job proposal from Aeritalía, and now I am in Torino (Italy) working on the Human Factors Aspects of the Columbus Space Station," says alumnus Francesco Brunelli. "I really do have to express my warmest gratitude to ISU. I owe it all to ISU."

Between 20 June and 20 August 1988 a group of outstanding students and young professionals came together as strangers and left as friends and colleagues. Coming from 21 different nations, but sharing a common dream and the qualities of perseverance, leadership and brilliance—these students have set out to change the world...together.

Investors in Space Leadership



The 104-member ISU Class of 1988 at MIT

Over 70 corporations and government agencies in more than 20 nations joined to support the ISU program when it began in the summer of 1988. Over US$1 million was raised to finance ISU Executive operations and the innovative ISU'88 program held at the Massachusetts Institute of Technology. In 1989 and beyond, ISU seeks to expand its network of supporters to include individuals and institutions to provide scholarships, curriculum and permanent campus development. Space Biospheres Ventures has already commited a five year scholarship and Life Sciences curriculum support to ISU. "We are delighted with the ISU program, level of excellence and international scope, and are proud to be sponsoring ISU's first textbook this year in the field of Space Life Sciences," says Margret Augustine, CEO and Project Director, Space Biospheres Ventures.

European Space Agency Director General Reimar Lüst has noted that, "[ESA] supports not only the 'principle' of the ISU, but also its day to day activities To date this has included free advertising in Agency publications, ISU brochure sponsorships and, in conjunction with the 1988 summer session, ESA sponsored scholarships and ESA staff as visiting lecturers." Lockheed Corporation has contributed a senior executive to serve full-time on the ISU summer session faculty for two months each in 1988 and 1989. "ISU is an important force for international space education and awareness. Few programs offer a more inventive and forward thinking approach to this vital frontier," says Lockheed Chairman and CEO Daniel Tellep. "We applaud ISU's efforts and are proud of our company's role in its continuing success."

ISU supporters, Margret Augustine of Space Biospheres Ventures, Reimar Lüst of the European Space Agency and Daniel Tellep of Lockheed Corporation.

ANNOUNCEMENT

An ISU Founders Association has been established to provide a vehicle for visionary men and women to become involved with and to support ISU's transition to a permanent campus in 1992. For more information on the Founders Association, contact:

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ISU extends its thanks to the following for their support of this supplement:

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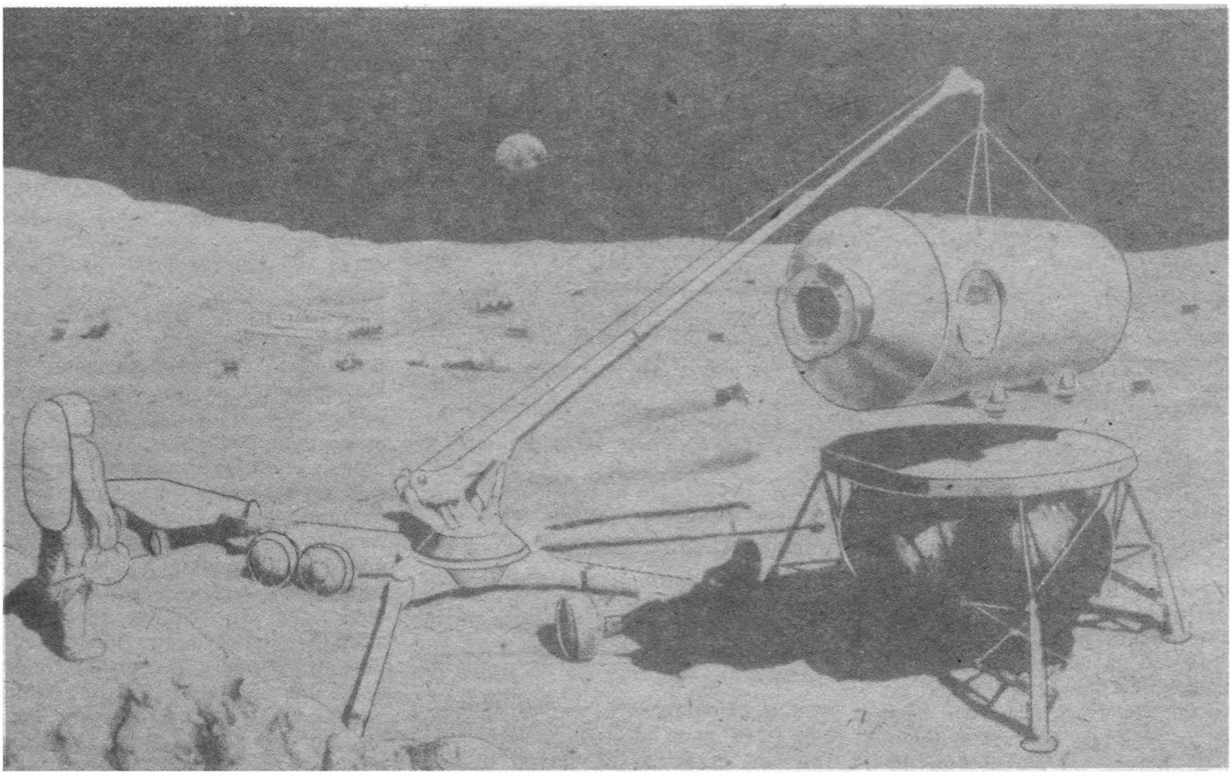
AVIATION WEEK

Deciding to Colonize the Moon



An artist's impression of a lunar mining complex.

The decision to establish a base on the eastern coast of Australia two hundred years ago has many points of comparison with the case for establishing a Lunar Outpost within a Space Industrial Infrastructure. The author argues that the growing global environmental problems will compel industrial nations to make such a major decision.

By J. Sved *

Australia

In 1988 Australia celebrated the bicentenary of the beginning of European settlement. The colonisation of Australia may serve as an analogue in the forum concerned with our future expansion into space and global survival.

Starting in 1616, dutch convoys followed the route from the Cape of Good Hope eastwards for 3000 miles and then northwards to Java, a course dictated by wind dynamics which would drive unlucky ships on to the barren western Australian coast. The motivation for such far-flung voyages was the feasibility of returning with goods both rare and valuable in the markets of Amsterdam, Madrid or London. Australia itself offered no such products of commercial value to the trading companiês.

A century and a half later in April 1770, the "hidden" east coast of Australia was sighted. Captain James Cook's missions were a manifestation of the rise of international commerce, the growth of science and the industrial revolution.

Cook's discoveries about Australia were not attractive for commerce minded colonists seeking to re-create a European way of life using a high value local product as a means of trade to obtain resources not locally available.

It appears that the arguments for using the east Australian coast as a port on an alternative route to China and as a site for a new colony were familiar to the British government. Sir Joseph Banks advocated in 1779 that a "thief colony" be established [1]. In 1784 James Matra, who had also sailed with Cook, promoted the idea of an Australian settlement [2]. The Pitt government, which was preoccupied by more pressing problems, was prodded, according to historian Manning Clark [1], by concern about a general revolt of diseased convicts.

However, historian Geoffrey Blainey [3] suggested that the strategic reasoning was that Norfolk Island had two resources vital for maintenance of England's naval power i.e. mast and spar timber plus flax of the best quality. The Australian mainland, 1600 km away would provide the infrastructure and greater potential for flax farming and production of sailcloth.

Both the Norfolk flax and Pine failed to live up to expectations. The flax posed problems of technology for canvas production due to its unrivalled length of fibrous material. The timber was found to be flawed and unsafe for masts. In both cases the usual sources of these materials were never denied to the British during periods of war.

In the nineteenth century Sydney was not only a port of call, on the way from Europe to Asia, it became a base for traders of goods obtained from the Pacific Islands. With their profits the business people developed the wool industry which was the first exportable product after 1830 [4].

The cost of maintaining the convict settlement was unexpectedly high. Instead of rapidly achieving self-sufficiency, Australia cost Britain the huge sum of one million pounds in the first twelve years. At the end of that

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period its population was only 5000. However, Australia's place on new trade routes was decisive. It prompted the rise of a free group of Australian traders who did not depend heavily on the favours of colony's governors, who were alert for new ways of making money and who eventually hastened Australia's transition from convict to free colonies by 1840.

The initial expenditure by the British government of one million pounds two hundred years ago is approximately equivalent to half a billion dollars today based on a simple weekly cost of living comparison [5]. Objectors, such as the East India Company, were concerned about loss of business monopolies [5] or other schemes for use of convict labour.

The decision to colonise a very distant land promptly was forced by the perceived problems of resources (convict accommodation and strategic materials). Perhaps there was a period of panic when the British government felt compelled to make provision for an alternative supply of strategic materials. After the decision had been made political considerations, as well as long communication delays, ensured that there would be no reversal. The costs may have been difficult to ascertain by critics. Eventually, a commercial momentum developed and the colony was able to supply marketable services.

Environmental Issues

The Earth's environment is now an issue of growing political importance as more adverse effects of the alterations caused by a century of industrial activity become apparent, even to non-technically minded people.

The consequences of interacting factors such as increased carbon dioxide in the atmosphere, destruction of the ozone layer, deforestation, thermal and chemical pollution and nuclear contamination are being recognised as the key points in ongoing research. A fleet of spacecraft will be put into operation in the 1990's to measure such global environmental parameters.

Extrapolative analyses that use some of the environmental characteristic parameters for dynamic models of global change have been attempted [6] but "world dynamics" modelling is open to question because the parameter measurements are incomplete and trends and interactions remain unclear. Most governments prefer to believe that technology will solve the problem in a "business as usual" manner. However, there are no models predicting a happy future without drastic intervention during the next century. Such scenarios do not contain much prospect of sustaining improved living standards for the inhabitants of Earth [7].

The 1988 drought in the USA prompted many climatologists to declare that the "greenhouse" effect may be building up faster than anticipated. The rate of CO_2 production from combustion of fossil fuels has already doubled the percentage in the atmosphere. Another ominous phenomenon appears to be hurricanes of increasing intensity resulting from the heat input in the Atlantic ocean during the northern summer. Models of solar heat trapping used in earlier studies may have been far too conservative. The well publicized destruction of the ozone layer by chlorofluorocarbons (CFC) is also contributing to the greenhouse effect [8].

Environmental crises will force governments to consider major corrective projects that will effect their short term political horizons. The space industrialisation option will be compelling. Transportation systems adequate for the task will be the priority.

Assuming that a catastrophe of hotter climate and rising ocean levels is much nearer than the next 50 to 100 years, the consequences and options for reaction need to be explored without delay. Conferences of specialists in fields related to or affected by the climate change have been sources of press reports acknowledging the impact of a warming climate.

An example of the perceived "business-as-usual" reaction option to warming and drying of agricultural regions is to develop hardier varieties of plants such as winter wheat. This technological fix will do nothing to reduce the climatic warm-up. Similar expert reaction may be observed in other specialist fields where some technological options for adaption may exist. The adaption to a degrading environment can go only so far before a major unpleasant change becomes unavoidable.

The source of more CO_2 in the atmosphere is well known i.e. fossil fuel burning power stations, transportation fuelled by combustion of fossil fuels and the destruction of vast regions of forest. It is clear that the reduction of these CO_2 sources would reduce the CO_2 problem by halting the increase. Natural CO_2 absorption through the long term carbonic acid cycle may eventually reduce the amount in the atmosphere. Nuclear power advocates push their technology as an alternative but the total replacement of fossil fuel burning power plants with fission reaction poses grave environmental problems from accidental leakage of toxic material. The long-awaited fusion reaction plants may be safer but this has to be demonstrated. Predictions of commercial fusion power production by 2050 are not encouraging.

Conventional solar power advocates characterised by the "Green" political movement believe that wind, tide and "direct" conversion of solar thermal radiation can ultimately replace fossil fuel power sources. So far the opportunities are limited to predominantly windy locations or even less numerous appropriate coastal areas. There are technical problems with wind power. The acquisition and maintenance cost of thousands of wind powered generators seems to be always greater than a large conventional power plant located close to the customers. The present market for solar energy systems for buildings demonstrates this by remaining modest. Energy savings are demonstrable but the incentives are reliant on legislation [9]. Replacement of fossil fuel burning power plants by terrestrial solar energy driven systems is not credible. Sites in deserts may be optimal today but a change to a more stormy climate may negate the marginal advantages.

Return to The Moon

Dr. Peter Glaser proposed, in the early 70's to build very large solar power satellites (SPS) located in geosynchronous Clarke orbit to beam microwave power to simple clean microwave antenna arrays on the Earth and then feed the recovered electrical current into existing power grids. This led to studies of large industrial infrastructures employing thousands of people in near-Earth space. Government funded studies were made in the late 70's following the OPEC led oil price increases. The reference scenario for these studies was the use of heavy lift reusable launch vehicles to lift all materials from the Earth's surface and Space Shuttle flights for personnel rotation. Why such a limitation was imposed is not clear. Perhaps consideration of the Moon or other Solar System resources was regarded by the study patrons as not politically fashionable. The conclusion was that the cost was not competitive with the then prevailing oil prices. As efficiency improvements subsequently forced down the demand and thus the price of oil, the urgency for development of an alter-

native to conventional power sources receded.

Some work continued in the Space Industry by people who were not compelled by Earth-only scenarios. The late Krafft Ehricke was a strong advocate of the use of Lunar Resources [10]. Those who had been inspired by Gerard K. O'Neil concepts considered asteroids as a supplementary source of materials not available on the Moon. A return to the Moon became an acceptable topic for several NASA supported symposia, after a hiatus in the early 70s.

The general view is that oxygen can be recovered from Lunar surface soil and used as rocket propellant. There are significant savings in launches from Earth when a LUNOX plant and associated space port are installed on the Lunar surface. A minimum amount of space traffic is necessary to break-even and then achieve true savings. Traffic models have been conservative by assuming no massive effort to construct SPS's until the technology has been demonstrated over some 20 years of Lunar Base operations. If hydrogen could be found on the Moon in sub-surface ice deposits in the polar regions or near suspected volcanic vents, the economics would be dramatically improved.

Aluminium and other metals can be recovered from Lunar rocks with processing plants that are transportable from Earth. Many volatile elements are available in abundance in the lunar regolith due to the solar wind which has delivered atoms for billions of years. These should be readily recoverable by processing the top 10 cm of scraped Lunar soil. The Helium 3 isotope has been identified as a high value exportable material. The customer would be the nuclear fusion power industry [11].

The Apollo 16 Lunar Module blasts off from the lunar surface. NASA

The Decision Forcer

Returning to the Australian analogy, one may now see parallels in the circumstances of major decision making. The Earth faces multiple environmental crises. The continuation of conventional practices does not inspire confidence. Politically unacceptable "Draconian measures" may be necessary to limit growth. The urgency today is debatable because there are still many people to educate about the relevant options.

The return to the Moon in order to establish a permanent human presence there is not regarded as a high priority by governments or commercial interests. The perceived cost of developing a transportation infrastructure does not appear acceptable without a convincing market plan.

The space domain today presents an established commercial sector for communications and several sectors providing services to governments in the areas of military data gathering and Earth monitoring. Further commercial growth is constrained by the perceived risks of building new infrastructures, including new cheaper to fly launch vehicles, to support new markets for high value goods manufactured or processed in space.

Governments of the major spacefaring nations are aware of a global resource problem as a limit to growth although this is not a current political issue. However, it seems that merchant-minded investors have realised the commercial attraction of a rapidly growing Space Industrialisation option to help overcome inevitable world problems. Environmental crises will force governments to consider major corrective projects that will effect their short term political horizons. The space industrialisation option will be compelling. Transportation systems adequate for the task will be the priority. The financing of spaceplanes, such as HOTOL, will be somewhat analogous to the Indian merchants who ventured to Sydney on speculation despite disincentives such as hostile naval activity and high insurance costs.

Soviet advances should not be overlooked and indicate the capability to undertake a major space industrial project. A manned presence on the Moon is far more credible than recently publicized manned Mars missions.

The political climate today is not tuned to supporting cures to environmental problems; only reactions to the symptoms. Natural climatic pressure will soon change this attitude. Alert governments will commit themselves to space endeavours that, at first, seem rash to the political critics. Spaceplane technology studies are increasing in the first world nations. The rationale may be disguised to avoid alerting the competitors: a scientific Lunar Base rather than an industrial Base.

There is however, a problem as waiting for environmental crisis to become politically obvious may be too late to avoid major disasters and disruptions. Complex engineering systems take time to reach operational status. HOTOL will possibly only fly after the year 2000 without the support of a crash programme.

The initial objective of producing Lunar derived construction material for orbital Power Stations may be found to be faulty but the prospect of no return on investment is not credible. Environmental crisis may be delayed by other terrestrial options such as global resource management (aided by satellite observations) and the Lunar infrastructure may demand more Earthly support than originally budgeted to sustain the growing infant. Ultimately, there will be unforeseen returns just as Australia produced unforeseen wealth.

The prospect of clean nuclear fusion power appears too distant to help, if the current "fusion in a test tube" controversy is discounted. The next most significant and much less radioactively hazardous, fusion reaction after Deuterium and Tritium is D + Helium 3. The required plasma containment and heat transfer technology is less demanding. Since Helium 3 isotope fuel is virtually non-existent on Earth the Lunar mining industry

would have a guaranteed initial customer and the nuclear power industry should consider space development as complementary to its interests rather than as a competitor for government funding [12]. This is analogous to Australian supplies of "yellow cake" Uranium Oxide to the established fission power industry.

Conclusions

Elaborations of these arguments must be prepared by specialists in the world-wide Space Industry. Criticism that the Space Industry is just a vested interest must be aggressively refuted. Critics must be forced to offer credible long term solution options or accept the Space Cause. Advertisements which advocate solutions to environmental problems using adequate Earthbound technologies should be refuted. The Space Industry needs to allocate funds to a low key but effectively sustained campaign to awaken the average citizen's interest in space based solutions to Earthly problems. Political acceptance of the merit of significant space budget increases for industrial and environmental goals must be encouraged.

Effort should also be redirected to the hard and dirty work of Lunar mining. A joint one-off venture by two superpowers would be just about as useful as another Apollo project. A more multinational endeavour, such as Lunar Industrial development, has far more human emotional (political) attraction if the prospects are sold effectively by public advocates [13].

An Intelsat style of international corporation must be established to focus the competitive energies of the major industrial players. This would call for tenders to fulfil space industrialisation operations concepts that are technically rather than politically determined [14,15]. Operational goals that help cure the global environmental problems as well as generating new economic domains will be drivers rather than political prestige projects.

As with any historical analogy, there are points of weakness. In this case the resources offered by the Moon and the rest of the Solar System are ultimately essential to avoid a drastic limitation to the growth of mankind. Australia has never offered that sort of benefit.

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CORRESPONDENCE

Justification for Space

Sir, Easter Island is a barren Pacific island that is famous for its great Stone Heads. But recent archaeological work indicates that originally this island, far from being barren, had the ecological balance of other Pacific islands with a plentiful supply of palm trees. The island was colonised by Polynesians probably about the 12th Century and it is suggested that over the succeeding centuries the palms were cut down in order to clear land for crop cultivation, to construct canoes and to assist in the erection of the giant Stone Heads. The population eventually increased beyond the capacity of the island to renew its resource of palm trees. Without the trees to replace worn or damaged canoes, the inhabitants were imprisoned on the island and the inevitable decline began.

It could be said that the Earth is an island in the vastness of space, that we are busily duplicating the Easter Island experiment on a global scale. Here then is my justification for going into space and for going now, within the next few decades.

When the global civilisation reaches the state in which the Earth is now, there are many conflicting requests for the money of any government, regardless of its political colour. There is a point of balance between the money which is available to sustain an industrially-based society, and that which is available for scientific endeavour. Briefly, any industrial nation uses more material than it can itself produce and inevitably produce more waste than it can handle this last problem can only be ignored in the short term by parking the problem on somebody else's doorstep. Eventually, however, options become limited and extremely expensive steps have to be taken, firstly to find and extract the minerals required by industry and secondly to clean up waste products. In the end, there is not enough money left for certain scientific activities perceived as non-vital - namely going into space. Civilisation then has no choice but to devote all its financial resources to the vital steps necessary to attempt to maintain itself this is only a short-term solution and doomed to failure. Civilisation will then have evoked the Easter Island factor - metaphorically speaking it will have condemned itself to a life on a island where all the trees have been cut down - where there are no resources left to build the canoes necessary to obtain materials from other islands to re-stock the barren land.

We are not quite yet at this point, but within a few decades we will be. Unless we go into space now, take what is perceived to be a selfish move in the face of so many competing calls for money, the we will go beyond the point where we can access the unlimited resources beyond the Earth.

Finally, it may now be necessary to add an additional factor to the Drake equation (the equation which can be used to determine whether intelligent life may exist elsewhere in the Universe). The present final factor is whether a technologically-advanced civilisation would explosively self-destruct.We must now add the Easter Island factor, ie., can a global civilisation make a move into space before it uses up its available resources, both mineral and financial.

SALLY LORD
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88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-8
(спейсфлайт)
По подписке 1989 г.

August 1989 US$3.00 £1.25

Spaceflight

The International Magazine of Space and Astronautics

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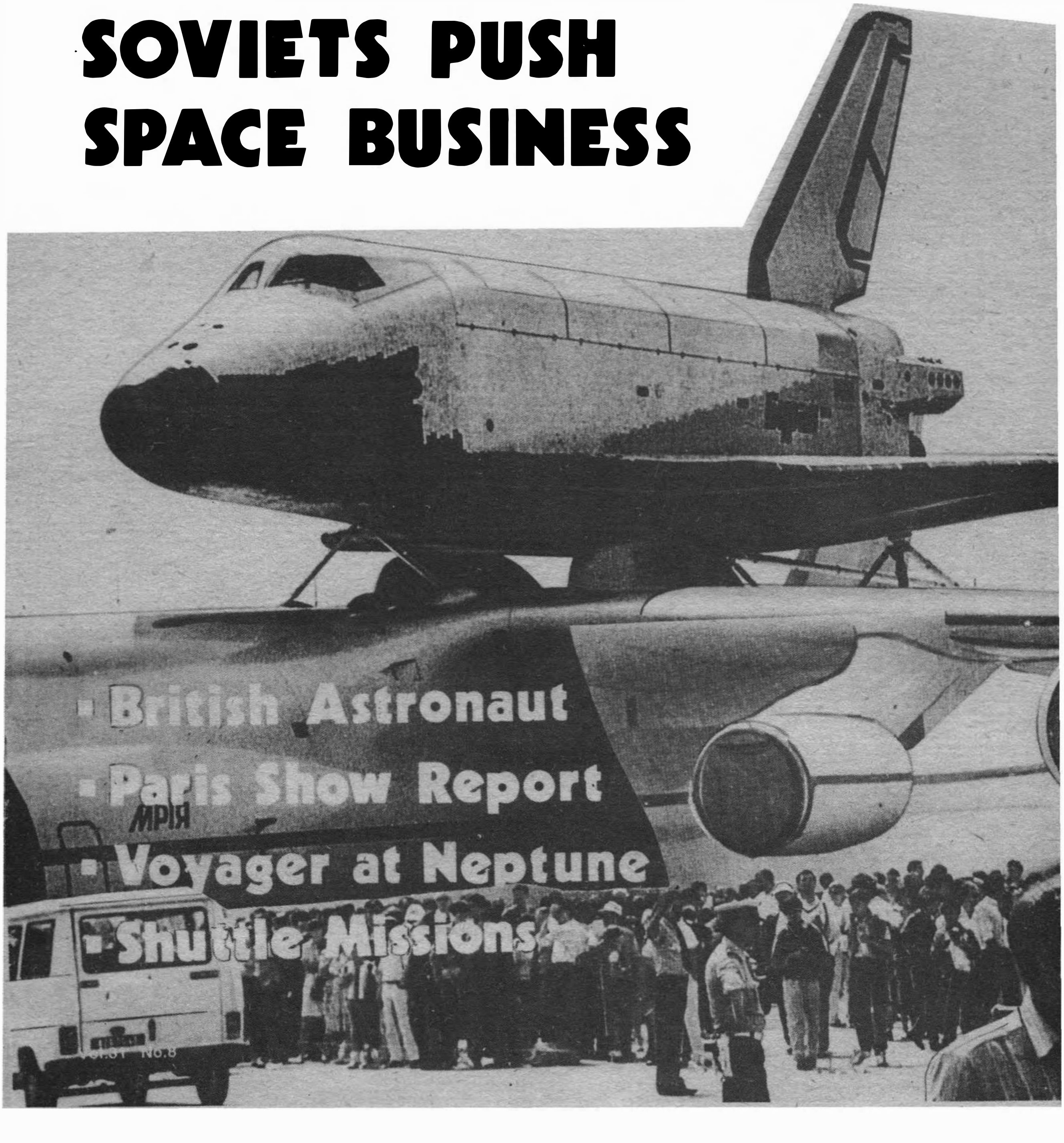

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Vol.31 No.8

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Spaceflight Office:
27/29 South Lambeth Road,
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DISTRIBUTION DETAILS

Spaceflight may be received worldwide by mail through membership of the British Interplanetary Society. Details from the above address. Library subscription details are also available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by AGB Impress, Cloister Court, 22-26 Farringdon Lane, London, EC1R 3AU. Tel: 01-253 3135.

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Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published monthly by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L., Ltd., Aylesbury, Buckinghamshire, England.

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Spaceflight

The International Magazine of Space and Astronautics

Vol. 31 No.8 **August 1989**

Cover Photo: Buran atop the Antonov Mriya dominates the sky line at this year's Paris Air Show.
Steven Young

Successful Launch of Olympus 1

The highly advanced Olympus 1 communications satellite, built by a consortium of aerospace companies led by British Aerospace, has been successfully launched by an Ariane 3 from the Guiana Space Centre, Kourou, French Guiana. The launch took place at 1.14 am BST on July 12 (9.14 pm local time on July 11).

Olympus 1, built under contract to the European Space Agency, is the world's largest and most powerful civil three-axis stabilised communications satellite. Designed as a technology demonstrator, Olympus 1 employs a range of innovative satellite and payload technologies.

Olympus 1, weighing 2,612 kg (5,758 lb) at launch, uses a bi-propellant fuel system to power the satellite's on-board liquid apogee engine (LAE) and 16 reaction control thrusters.

The LAE which provides low thrust will enable the solar arrays to be deployed before firing so providing the satellite with electricity from the transfer phase to geostationary orbit. Throughout transfer the satellite is three-axis stabilised (rather than the conventional spin-stabilised), enabling efficient use of fuel and precise on station positioning.

Olympus 1 will arrive at its final geostationary orbital position at 19° West between seven and 21 days after launch. Once on station the satellite will undergo extensive in-orbit tests with the completion of the commissioning phase some 90 days after launch.

Olympus 1 benefits from a sophisticated Attitude and Orbital Control System providing highly accurate pointing for its four communications payloads. These payloads will demonstrate new types of communications systems aimed at stimulating the introduction of new satellite based services and techniques.

Olympus 1's flexible solar arrays provide the spacecraft with up to 3.6 kW of electric power. The Olympus power subsystems and design can accommodate larger arrays measuring up to 56 m (184 ft) from tip to tip. Future Olympus satellites could therefore provide up to 7.7 kW to meet predicted trends for increased power which will be necessary for future high powered services such as high definition direct broadcast television.

Arianespace Joins OSC and Hercules In The Pegasus Project

Orbital Sciences Corporation (OSC) and Hercules Aerospace Company of the United States and Arianespace of Europe have announced a preliminary agreement concerning marketing and sales of the Pegasus air-launched space booster.

Pegasus is pioneering an innovative approach for launch of small satellite payloads (see p. 269). Pegasus launch services have been purchased by the United States Government and commercial customers for low-orbit and geosynchronous-orbit applications. With first launch scheduled for August 1989, Pegasus will complement present ground-launched vehicles for scientific, defence and commercial missions.

The Memorandum of Understanding signed by OSC, Hercules and Arianespace outlines terms of cooperation under which Arianespace will exclusively market and sell Pegasus launch services in Europe. During the initial period of two years, the parties will evaluate possible activities including performance upgrades to Pegasus and establishment of a European base of operations.

NEWS IN BRIEF

Voyager Discovers New Moon

Voyager 2 has discovered a new moon orbiting Neptune. The moon has been designated 1989-N-1. Two moons were previously known to be orbiting Neptune - Triton and Nereid. Voyager will make its closest approach to Neptune on August 25.

New Parliamentary Space Committee

A new Parliamentary committee is to be established to act as a forum of discussion for parliamentarians and industrialists in order to promote a better understanding of Space activity in the United Kingdom and the economic, technological and scientific benefits which it brings. The committee, to be known as the "Parliamentary Space Committee" is to be formed to include Members of Parliament who belong to the All Party Space Committee, and member companies of the United Kingdom Industrial Space Committee (UKISC) and British Association of Remote Sensing companies (BARSC). The group intends to operate in a similar way to other Parliamentary Committees which have been influential for a number of years in the technology sectors of British business.

European Astronauts

On June 28, 1989 during its meeting at ESTEC (European Space Research and Technology Centre) in Noordwijk, the Netherlands, the ESA Council unanimously approved the policy on European astronauts. The policy for European astronauts is the basis for the operation of the Columbus and Hermes Programmes, which are the key to further European manned space flight. A single European astronauts corps for the ESA mission will be set up under the authority of the Director General. The policy defines the selection procedures for the European astronauts. The pre-selection will be done by Member States. The final selection will be ESA's responsibility. The aim is to have at least one national from each Member State to become a member of the corps.

Satellite Damaged by Crane

The INSAT-ID Indian communications satellite has been badly damaged after it was hit by a crane's hook while it sat atop a Delta II launch vehicle at Cape Canaveral Air Force Station. The satellite has been removed for inspection and the launch has been postponed indefinitely.

Ariane Contract For UK Firm

The UK firm EASAMS Ltd has announced the receipt of a £1.1m order for the further supply of flight software for the vehicle. EASAMS, provides the on-board guidance and control software for Ariane. These Flight Programmes guide the launcher throughout its flight.

SDI Payload For Delta

McDonnell Douglas has won a contract to launch the Low-power Atmospheric Compensation Experiment (LACE) and the Relay Mirror Experiment (RME) on a Delta II rocket for the Strategic Defense Initiative (SDI).

The LACE experiment involves a satellite which will study the distortion effects of the Earth's atmosphere on laser beams and to what extent these distortions can be removed.

RME features a cylindrical satellite that is to orbit the Earth for about six months with a mirror pointed toward the ground. The goal of the experiment is to demonstrate that a space mirror can be used to accurately capture and point an unlinked ground based laser beam.

This marks the 9th Commercial rocket contract for McDonnell Douglas and is scheduled for launch in late 1989.

Sweden Joins Space Station Project

Sweden has become a participant in the ESA Columbus development programme and will be subscribing 1% of the programme's budget.

'The request to join the Columbus programme was presented by the Swedish Delegation during ESA's Council meeting held on June 28-29, 1989 at ESTEC (the European Space Research and Technology Centre) in Noordwijk, the Netherlands. The Columbus programme is the Agency's contribution to the Freedom Space Station. With this decision, Sweden becomes the tenth ESA Member State to join the Columbus development programme.

(Above) NASA Administrator Truly, on the far left, welcomes home the crew of STS-30. See p 260 for a full report on this mission *NASA*

Truly Confirmed as Administrator

The nominations of Richard Truly for NASA Administrator and J.R. Thompson as deputy have been approved by the US Senate.

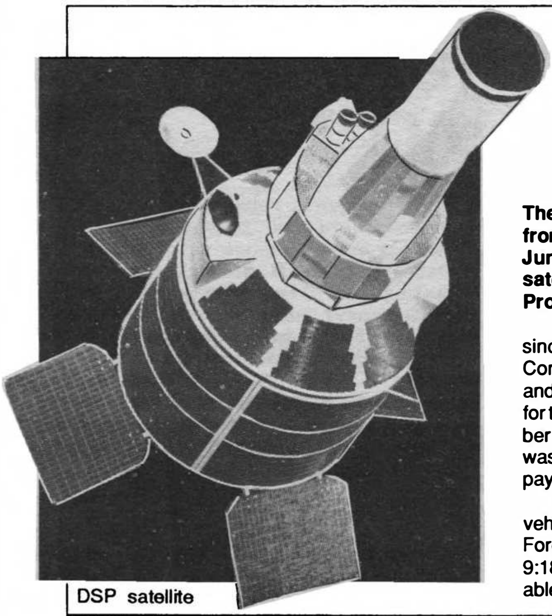
The confirmation followed passage of bills in both the Senate and the US House of Representatives that waived the requirement for the administrator to come from civilian life. The bills require that Truly retire from the US Navy within 60 days of his confirmation and allowed him to retain his rank, status and pension as a retired Navy officer. Truly officially became NASA Administrator at a short swearing-in ceremony held at NASA Headquarters in early July.

NASP to be Scaled Down

The National Space Council is expected to recommend to President Bush that the goals for the National Aerospace Plane (NASP) should be made less ambitious.

The project has already had its budget cut for 1990. US Defense Secretary Richard Cheney wanted to end Air Force participation in NASP, giving NASA full responsibility for the project. But it is believed the National Space Council will recommend the Air Force continue funding NASP because of the craft's possible military applications.

(Right) An 80-foot mock-up of the NASP appeared at this year's Paris Air Show, dominating the US Pavilion See p.265 for reports on the Air Show



DSP satellite

First Titan 4 Launches Early Warning Satellite

The first Martin Marietta Titan 4 blasted off from Cape Canaveral Air Force Station on June 14 carrying a military early warning satellite known as DSP (Defense Support Program).

The Titan 4 has suffered a series of delays since it was assembled on the launch pad at Complex 41 in May 1988. Hardware, software and shakedown problems dogged preparations for the first launch, originally scheduled for October 1988. One of the more serious problems was doubts over the structural integrity of the payload fairing.

Last minute checks on June 14 gave the vehicle a clean bill of health. A joint industry - Air Force team gave the go for launch and at 9:18am EDT America's most powerful expendable launch vehicle roared into the sky above Cape Canaveral. The Titan's payload, a DoD early warning satellite named DSP, was successfully placed into orbit.

The DSP satellite's infrared sensors are designed to detect the rocket exhaust of a nuclear missile from its vantage point in geostationary orbit. The satellite will also be used to record valuable information on Soviet missile tests and space launches. DSP's sensitive detectors are thought to be capable of tracking aircraft flying on afterburn.

The Titan 4 is able to lift 4,536 kg to Geostationary Orbit and 17,690 kg to Low Earth Orbit from Cape Canaveral. The booster can also make launches from Vandenberg Air Force Base to place satellites into polar orbit. The Air Force expects to launch six Titan 4s per year by 1993 and nine per year from 1995.

Soviet-Austrian Space Flight Details

By Johannes M. Fritzer and Neville Kidger

In 1988 Austria agreed with the Soviet Union to participate in a joint space mission to the Mir orbital complex. The flight is a commercial venture, with Austria reportedly paying about ten million dollars for the flight.

An Austrian official revealed that the agreement covered payment for elements in the flight such as training and launch services.

A TV and newspaper campaign was mounted to invite applications.

The first round of medico-psychological examinations began on about 50 persons on February 20, 1989. The cosmonaut should possess the medical, psychological and physiological classification of a full fighter jet pilot However, pilots are to be excluded from the selection. The second leg of the selection began in June and involved the assistance of Soviet experts.

As a result the group is to be reduced to between 10 and 15 candidates.

A Soviet-Austrian team will pass a resolution to allow six of these to enter the third and final stage which will begin in Moscow in September. At this stage the two finalists will be decided.

Training should begin in December 1989 and will last for one-and-a-half years.

Experiments

On March 10, 1989 the Austrian Minister for Science and Technology chose 15 experiments for the flight. A total of 34 experiment proposals were received. Total mass of the experiments is 150 kg and the time allocated to them in space is 42 hours.

Of the experiments, 11 are of a medical nature, three are technological in nature and the final one is a remote sensing experiment.

On April 6, 1989 a meeting was held between the Soviet and Austrian sides at Graz, the administrative centre of Styria. This is one of many meetings before the flight, which should take place in 1991.

Experiments for the 1991 Soviet-Austrian Space Flight

MEDICAL EXPERIMENTS

MONIMIR (Motormonitoring in Space)
Analysis of postural reflexes in zero gravity and the development of a computer based neurological measurement system.

COGIMIR (Cognitive Functions on Mir)
Analysis of cognitive functions during spaceflight conditions.

LUNGMON (Lung Monitoring)
Testing of a electrical heart and lung monitoring system.

DOSIMIR (Dosimeter on Mir)
Dosimetric monitoring of the austrian cosmonaut and testing of a TLD space dosimeter.

PULSTRANS (Pulse Transmission)
Analysis of pulse transmission and heart frequency during changes of body position and during strain.

MIKROVIB (Microvibrations)
Analysis of spontaneous and stimulate microvibrations of the body surface in zero gravity.

BODYFLUIDS (Bodyfluids)
Measurement of the velocity of sound in vein blood of the cosmonaut to determine the dynamics of transient fluid motions after volume effective stimulations.

OPTOVERT (Optokinetic Vertical Vectionperception)
Vertical vectionperception via optokinetic stimulation in zero gravity and comparison with ground conditions.

MIRGEN (Genetic Material on Mir)
Analysis of space flight effects on genetic material via blood sample analysis before and after the space mission.

AUDIMIR (Binaural Audio Experiment on Mir)
Analysis of binaural technology for the cosmonaut communication system and its impetus on the sense of balance in zero gravity.

MOTOMIR (Human Motorics on Mir)
Neurophysiological analysis of human motorics during defined movements in zero gravity on the space station Mir.

TECHNOLOGICAL EXPERIMENTS

BRILLOMIR (Brillouin-Strewing on Mir)
Measurement of critical fluctuations during decomposition of binary liquid mixtures in zero gravity via Rayleigh-Mandelstam-Brillouin-Strewing.

LOGION (Low Gravity Ion Emitter)
Testing and determination of working characteristics of a liquid metal ion source in zero gravity to be used for potential control of spacecraft.

MIGMAS (Microgravity Mass Spectrometer)
Testing of a mass spectrometer for microgravity microanalysis which might be used later on COLUMBUS or on a cometary mission.

REMOTE SENSING EXPERIMENT

FEM (Fernerkundung auf Mir)
Use of MKF-6 multispectral camera for remote sensing experiments.

Search for UK Astronaut Underway

Speakers at the London press conference to launch the Juno project (left to right) Dr Gregg Briarty of Nottingham University, Mike Parker, deputy managing director of Saatchi & Saatchi, Peter Graham, Juno Mission Director, Sergey Konychev, deputy chairman of the Moscow Narodny Bank and John Wodger director of MSL International

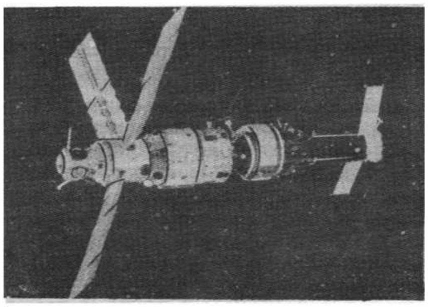
The first Briton in space will be launched from the Baikonur Cosmodrome in 1991 under an agreement signed in Moscow on June 29. The search to find the British astronaut is underway through a nationwide advertising campaign. The eight day mission will be the first to be financed entirely by the private sector.

The Anglo-Soviet space flight was announced at simultaneous press conferences held in London and Moscow linked live via satellite. The historic agreement was signed by Glavkosmos and VVO Licensintorg, which acts as Glavkosmos' foreign trade agents, and Antequera Limited, a specially formed British company. Lord Young, UK Trade and Industry Secretary was present at the signing, and wished the 'historic project' every success.

The mission, named Juno (after the Roman goddess of marriage), will take place between March and July 1991. The British astronaut will be launched onboard a Soyuz TM spacecraft and dock with the Mir space station. Two British astronauts - a prime candidate and a backup - will train for 18 months at Star City in the Soviet Union. During the mission the back-up astronaut will conduct duplicate experiments on the ground to compare results with the experiments carried out in orbit.

The search for the British astronaut is being led by Air Vice-Marshall Peter Howard in cooperation with recruitment consultants MSL International. The successful candidate will be a fit and healthy man or woman aged between 21 and 40. A science degree and the proven ability to learn a foreign language are also necessary - the two finalists will have to learn to speak Russian fluently.

The day following the announcement of the mission advertisements appeared in the national press proclaiming "Astronaut wanted no experience necessary". Prospective candidates were invited to call a special telephone line to obtain an application form. By the time the telephone lines closed on Friday July 14, over 12,000 phone calls had been received.



The Mir space station in orbit

After the closing date for applications on July 24, an initial 'long-short list' of 300 will be drawn up, this will be whittled down to a 'short-short' list from which the two finalists will be selected.

Funding for the mission in entirely from the private sector. The £16 million costs of the Juno mission will be covered by the sale of sponsorship and merchandising packages. The Moscow Narodny Bank is providing start up assistance to Antequera by coordinating the mission's marketing and finance from its London headquarters. A marketing team from the Saatchi and Saatchi group will be responsible for creating a high level of interest in the mission among the general public and the business and science communities. Encouraging sponsors to fund the mission will be a key task.

Professor Heinz Wolff of Brunel University, Middlesex, is to chair a selection board to decide which experiments and equipment from industry, universities or research establishments will be flown on the mission. The mission is limited to between 100-300 kg of scientific experiments, with only 10 kg permitted to return to Earth. The equipment required will push forward miniaturisation technology. All experiments must be simple to operate and robust enough to survive the launch phase. Scientific work during the eight day flight will concentrate on microgravity and medical experiments. Professor Wolff hopes, "the results of the experiments will add significantly to mankind's knowledge."

(See overleaf for an interview with Peter Graham, Juno Mission director.)

"This Mission is for All of Britain"

The day after the signing of the historic agreement to launch the first Briton into space *Spaceflight* spoke to Peter Graham, Mission Director of the Juno project. Mr Graham revealed the background to the project and his hopes for this exciting project.

Mr Graham can you tell me a little about yourself, your background and how you became involved in the Juno project?

I'm British born although clearly by my accent I've been overseas for a number of years, primarily in Canada. I am a lawyer by training. I have graduate finance degrees from universities in France. I was working on large projects in Canada, not necessary directly related to putting people into space, but some of them were connected with the space and defence industries When British businessmen were approached by Glavkosmos to put this space mission together they were looking for someone with experience in large projects to manage it and that's how I became involved.

What are the origins of the joint mission?

The idea was formulated by a group of British business people - some of whom are no longer involved - almost 18 months ago. They approached Glavkosmos which quite frankly has something we need in Britain - they want to sell it and we are interested in buying it. People like Heinz Wolff and Peter Howard have been involved from the start of this programme and are key players. Because it's a private enterprise venture there have been a lot of difficult negotiations with the Soviets that we have had to follow through to conclude a contract and negotiations only concluded a number of weeks ago.

Was UK Government financial support for the project ever a possibility?

The Government was really never approached. The business men involved feel that it has enough British industry support and the benefits to British industry are significant enough that the private nature of this can go forward. Clearly we have discussed the mission with British officials and by Lord Young's presence yesterday there is support for the project. Any government has a lot of expenditures to cover and they've got to make tough decisions on which expenditures get funding and which do not. The project is something that British pnvate industry can manage. What we do need is Government cooperation, but not necessarily Government finances.

Did you need Government permission to go ahead with this project?

The Government did not have to give us formal consent and we were not looking for it. But clearly you do not want to take on an international project of this magnitude without discussing it with Government officials. Because quite frankly they can help, in certain the areas.

Part of the funding of the mission will come from sponsorship - will this involve company logos on space suits etc.?

As we have seen since the launch yesterday, the project is capturing the imagination of the public. This is not going to be unrecognised by business leaders. It is going to be a great opportunity for businesses to promote their products and services. I think when you do a project like this, first and foremost the scientific side must take priority and be separate from the commercial side. But as a good businessman you've got to cover your expenditures by generating revenues. So yes people will be able to put their products and their company logos on the space suit and the rocket. There is a real opportunity to promote the technology that has been learnt in space. We are not trying to make this a circus, we are trying to make this a strong marketing effort which will give a high profile for those companies interested.

What will happen to the capsule when it is returned to Britain after the mission?

What we would like to travel the country with the capsule. The purpose for this mission is for all of Britain to get exposure. The exposure to children on an educational level is going to be very beneficial. I hope that the capsule will travel around and that the children in Scotland, Wales, England and Northern Ireland will get exposure to this. I think it is very important that everybody gets exposure to it. Whether it returns to one location after a period of touring is something we will have to decide. We will have to find the appropriate place.

You mentioned the educational importance of this flight - will school children be given the chance to fly an experiment with the British astronaut?

I think you are probably aware that one of the most captivating experiments in the American programme was submitted by school children and that was to see if a spider could spin a web in space. I think that the input of children is high on our priority level. They will certainly be able to submit an experiment and we are setting up the structure in which they can do that. It's an opportunity that can't be missed. We would like to do a lot of things for children - perhaps form a space cadets type of programme. There are a number of projects we can do for children aimed at an educational level.

How will payload space be sold to experimenters?

It's going to be limited to UK companies. We have a weight restriction - we are allowed up to 300 kg of experiments. It will not go to the highest bidder. In fact if we feel some experiments are important enough we will fund them ourselves. We want to return the scientific results back to Britain and have industry, institutes, schools and the public learn from them.

Can arrangements be made to increase the payload mass if necessary?

Well the Soviets are good businessmen and they recognise there has to be flexibility in any negotiations. We do have flexibility and if something were to come up which was of a special nature we could negotiate with them. But at the present time the limit is 300 kg.

Does the figure of £16 million include your own administration, publicity and recruitment costs?

Yes.

Can you tell me the how much Glavkosmos is charging for the actual flight?

I cannot tell you the actual figure I can say our science budget is estimated at about £3 million. Our overhead is very small so the £16 million is very close to the figure we are being charged.

How confident are you that you can raise the £16 million?

Very confident. The difficulty we have with this project from a business stand point is there is a bit of scepticism as to who is behind the project. There were corporate chairmen from five different corporations in Moscow yesterday and two in the London audience who have expressed interest. The size of this project deems that they call the shots when they want to announce their involvement. Because obviously they want to structure their marketing plans and promotion plans as finely tuned as they can have them. Unfortunately at this stage we can't reveal all the facts and that of course will lead to an understandable amount of scepticism to start with. But I think the press will be pleasantly surprised with some of the announcements that are going to be made over the next few weeks as to the involvement of different people and organisations in the project.

So we are going to see a very active period in the next few weeks?

Because this is the first project of its kind to

be privately financed there is an inner circle of people who are standing, with an outer circle of people who are watching to see if it will go ahead. Until the inner circle goes, the outer circle is not going to do anything. We have put together a management team and spent some seed money and developed some aspects to make this thing go. When people started to see what was happening over the last few weeks, they began to realise how serious this is. I think we are going to have a very active period over the next few weeks, with the selection and naming of the astronauts, but also the announcement of the involvement of British industry and individuals.

Do you expect to make a profit out of this?

Well I would not be a good businessman if I did not say I wanted to get a little bit of a profit. Our goal of raising £16 million basically covers our expenditure. So if we can raise more than that I've done a good job. Yes I would like to see a profit because I would like to see more of these missions go up. There are options within our contract with Glavkosmos for other launch dates. I would like to see a number of British astronauts go up. It will be very exciting.

So this mission is not a one-off. It is not a gimmick as some people would like to portray it as?

No, absolutely not. Its too high profile of an event to be a gimmick. It is really scary how difficult it is to do this, on many fronts - the science side, the negotiations and politics involved with two nations joining together and from a business side it is very difficult. So no, this is not a one off.

You mentioned the option of further flights what sort of frequency are you talking about - once a year, every two years?

As you will appreciate the minimum lead time to train the astronaut is eighteen months - that's the guidelines from the Soviets, they would prefer two years. So we do not see a second flight until probably 1993 or 1994.

Do you think you can sustain public interest and the support of sponsors to maintain such a flight rate?

I think it would be naive of me to yes to that. I think the public is intelligent but grows tired of things very quickly. I believe the viability here really comes from British industry. The Russians have technology that British industry needs. The first flight will demonstrate to British Industry what can be done in space, in particular microgravity experiments. I believe that aspect of it will be sufficient to fund - or to supplement - future mission funding. Clearly with any event that is reoccurring there will always be interest. You have to think of some of the things that will happen here, it will be astronomical. The station goes around the Earth approximately 16 times a day I understand. Some of the film footage out of that will be just gorgeous to see Britain on a nice clear day.

Is it one of your requirements that the station makes over flights of the UK during the mission?

The ' Astronaut Hotline' team answered more than 12,000 calls in two weeks

Yes definitely, we would like overflights of the UK. One day we would like everybody in Glasgow to turn their lights on at night so the astronaut can see them and on the next time round Belfast, and so on.

Can you tell me what areas were covered by the contract signed yesterday?

The contract covers all aspects of the mission. It covers everything from the business side to the scientific side to the selection. It is extremely detailed - we have medical criteria listed that the astrbnaut must meet, everything from the sugar count in his blood to his eye vision. It covers the rights and obligations under the contract for both parties - what Glavkosmos must do and what we must do and aspects of safety to ensure our astronaut is returned safely to Earth, aspects related to setting up the laboratory in the Soviet Union to monitor the space experiments on Earth as well as in outer space. It is about a 120 page contract, so it took a great deal of drafting and re-drafting and negotiation.

There was a false start back in April when the signing of the contract was postponed. Can you explain what happened?

There was a different group of people involved at that point. There was not a contract at that time, that was the problem. I cannot really comment on why.

Jack Leeming's name was often mentioned as one of the organisers of the British astronaut project. Is he still involved?

Mr Leeming is an extremely important man in the British space industry, he is extremely knowledgable. He has been talking to me almost daily, we had a conversation last night. I think he is vital to the project and I would like to see him involved. As you can appreciate with the magnitude of launching this programme there is a lot of backroom negotiations going on with individuals, institutions and companies. And again you may be surprised what comes out in the next few weeks with the announcement of individuals involved.

In the past Soviet space officials have criticised short flights as unproductive. Is the flight limited to eight days purely due to the cost or is this something the Soviets have imposed?

It really relates to the programme the Soviets have put in place for the use of their Mir station at this point. There will be Soviet missions before and after ours. There will be joint missions after ours - in our contract it clearly states no European country will be going up before us. So it really relates just to the schedule of how Mir is going to be used.

Have the Soviets been very open about their plans for the space programme?

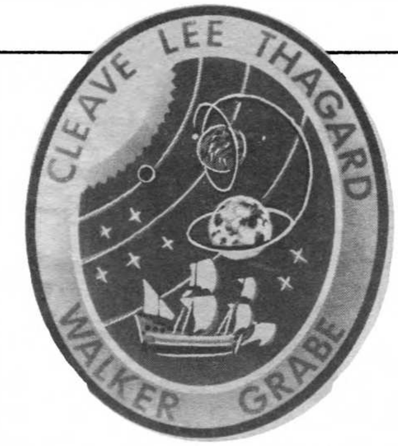
Extremely open, in fact almost surprisingly open. I think you get a little sceptical about the Soviet approach until you sit down and deal with them. They have got some excellent technology, they have a space administration which has a great history to it. They have been very cooperative, very open. There will be footage that will be supplied to the mission that has never been seen in the West before. We view this is a great chance to share the experience with the British people. So we will get lots of live television coverage down to Britain.

Finally, it has been almost 24 hours since you launched the search for Britain's first astronaut - what's the response been so far?

Unfortunately a little bit higher than we expected. As you know the newspaper advertisements are in the papers this morning, so we were not sure we would have much response yesterday. We actually received 600 phone calls. We were thinking we would average 200-300 the per day. So that's 600 on our first day without the advertising and I think we're going to have a great deal more over the next few weeks. It will be a big process screening the candidates, but we've got a good team.

Atlantis Extends the Shuttle's Reach

The STS-30 mission marked the first deployment of an interplanetary probe from the Space Shuttle. The Magellan probe has begun its 15 month journey to the planet Venus where it will accurately map the surface with a powerful radar system. Onboard Atlantis for the four day flight were: Commander David Walker, Pilot Ronald Grabe and Mission Specialists Mark Lee, Norman Thagard and Mary Cleave.



The STS-30 patch depicts the joining of NASA's manned and unmanned space programmes. The Sun and the inner planets of our Solar System are shown with the curve connecting the Earth and Venus symbolising the Shuttle orbit, the spacecraft trajectory toward Venus and its subsequent orbit around our sister planet. A Spanish caravel similar to the ship on the official Magellan programme logo commemorates the 16th Century explorer's journey and his legacy of adventure and discovery. Seven stars on the patch honour the crew of Challenger. The five star cluster in the shape of the constellation Cassiopeia represent the five STS-30 crew members. ***NASA***

Launch Preparations

Processing activities began on Atlantis for the STS-30 mission on December 14, 1988, when it was towed to Orbiter Processing Facility (OPF) bay 2 after its return from Edwards Air Force Base, where its previous mission, STS-27, was completed with a landing on December 6. Post-flight deconfiguration and inspections were conducted in the OPF.

As planned, the three main engines were removed and taken to the main engine shop in the Vehicle Assembly Building (VAB) for the replacement of several components. During post-flight inspections, technicians discovered cracks in one of the high pressure oxidizer turbopump bearing races on the number 3 main engine. The pump was removed and sent to Rocketdyne for analysis. It was determined that the most likely cause for the cracks was the presence of moisture inside the pump which lead to stress corrosion. The production process of the pumps was modified to eliminate the moisture.

Atlantis' three main engines were re-installed with the defective turbopumps still in place (engine 2027 in the No.1 position, engine 2030 in the No.2 position and engine 2029 in the No.3 position).

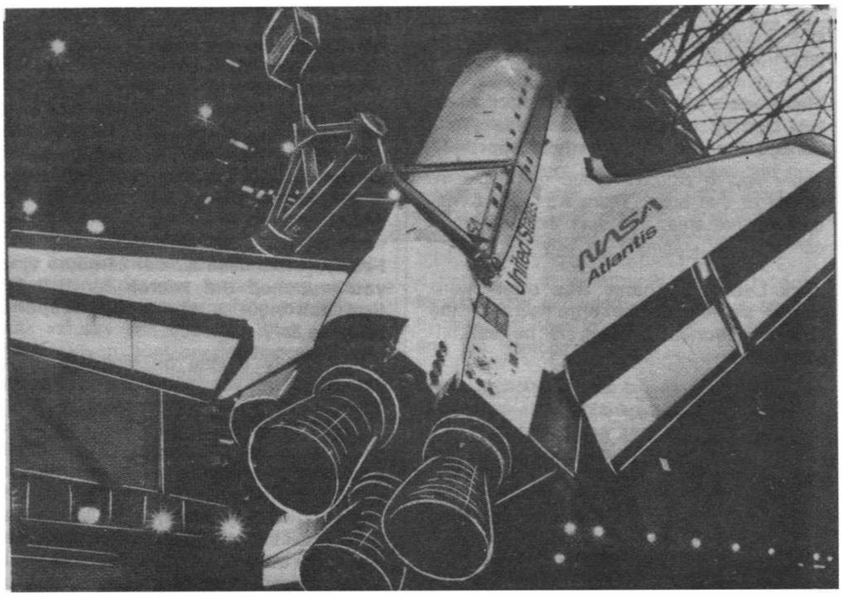
The right-hand Orbital Manoeuvring System pod was removed in early January and transferred to the Hypergolic Maintenance Facility for repairs of a helium regulator that had failed during STS-27. The regulator was re-installed on February 9, 1989.

Stacking of the Solid Rocket Booster (SRB) segments began with the left aft booster on Mobile Launch Platform 1 in the VAB on January 2. Booster stacking operations were completed on February 19 and the External Tank was mated to the boosters on March 2.

The assembled Shuttle vehicle was rolled out of the VAB to launch pad 39B on March 22.

The Terminal Countdown Demonstration Test was carried out on April 6-7

Atlantis is hoisted into the vertical position in the VAB during preparations for STS-30. *NASA*



Magellan Preparations

The Magellan spacecraft arrived at KSC on October 8, 1988. It made the trip from Martin Marietta's Denver plant aboard a specially cushioned, instrumented and environmentally controlled truck-trailer. Upon arrival at the space centre the probe was taken to the Spacecraft Assembly and Encapsulation Facility-2 (SAFE-2)

The forward equipment module and spacecraft body were mated with the liquid propulsion module on December 21 Magellan's radar module was installed on January 6, 1989. The storable propellants that will be used for mid-course corrections and spacecraft control at Venus were loaded aboard on January 18. The probe was then mated with the Star-48 solid propellant motor on February 3. The two solar panels were attached and tested on February 5.

On February 15 the spacecraft was moved to the Vertical Processing Facility where it was mated with its Inertial Upper Stage (IUS) booster two days later.

A test was run to simulate Magellan's deployment from Atlantis' payload bay. STS-30 Mission Specialists, Mark lee and Mary Cleave participated in the deployment exercise.

Having successfully completed its pre-launch checkout, Magellan was placed inside the payload canister and moved to the launch pad on March 17. The probe was transferred to Atlantis' payload bay on March 25 and the connections made between the Magellan and the Shuttle.

First Launch Attempt

Weather at the Cape on April 28 was described by meteorological officers as "perfect weather to go flying". But other factors were to stop the launch that day.

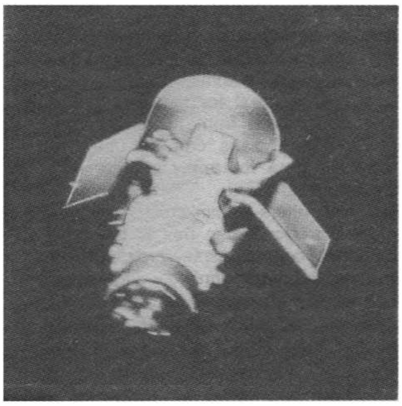
The countdown - one of the smoothest in Shuttle history - reached the T-9 minute point without incident. However during a planned 40 minute hold a problem with a range safety console became apparent. The Range Safety Officer would not give a 'go' for launch until the console recovered. The countdown finally resumed only to be halted at T-31 seconds when a problem was detected with a recirculation pump in Main Engine No.1. The pump's electrical system was shorted out by fragments of metal floating in the liquid hydrogen. The pump is used to recirculate hydrogen through the fuel lines to keep them cool and in condition for ignition. A further problem was discovered after the launch had been aborted. Television cameras picked up a vapour cloud near a hydrogen pipe linking the External Tank to the orbiter. Closer examination after the crew had left Atlantis and the vehicle had been safed revealed a small hole in the pipe's casing, which was allowing hydrogen to escape.

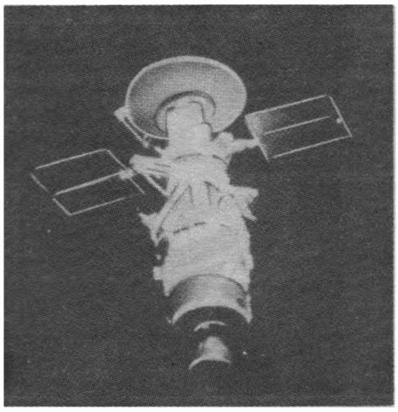
The recirculation pump was replaced with one from OV-105 - now named Endeavour - which is under construction at Rockwell International's Downey plant in California and a new hydrogen pipe installed. The launch was rescheduled for 18:48 BST on May 4.

Launch

On launch day cloud cover over the Shuttle Landing Facility (SLF) adjacent to the launch area was a major concern. If Atlantis had suffered a malfunction which required an abort during the ascent phase of the mission the crew would have performed a Return to Launch Site Abort (RTLS). This difficult manoeuvre requires the Shuttle to reverse its course in order to make a landing back at the Kennedy Space Center. The mission rules required visibility limits at the SLF which the cloud violated. Satellite pictures indicated the Kennedy Space Center was the only location in the area which had cloud cover! The countdown was held at T-9 minutes awaiting a 'go' from the meteorological teams.

Fortunately, as the launch window ticked away the cloud cover became more scattered and it was decided to continue with the countdown until T-5 minutes where it would hold until the weather was within the limits. The countdown was resumed at 19:42 BST and continued without interruption. Atlantis and her crew of five blasted off from Pad 39B at 19:47 BST, with just two minutes remaining in the launch window. During ascent heavy yaw steering was used to place Atlantis into the precise orbit for the deployment of Magellan.





Magellan's solar panels are deployed. The opening of the solar array was photographed through the orbiter flight deck aft windows. *NASA*

The SRBs separated at T+2 min 5 sec and were later returned to Cape Canaveral. (The boosters were disassembled and fully examined. There were no signs of abnormal damage in the joint areas.) After main engine cut-off at T+8 min 31 sec, two Orbital Manoeuvring System (OMS) burns were made. The first to boost the altitude the and second to circularise the orbit.

Day One: May 4, 1989

As soon as post insertion checkouts

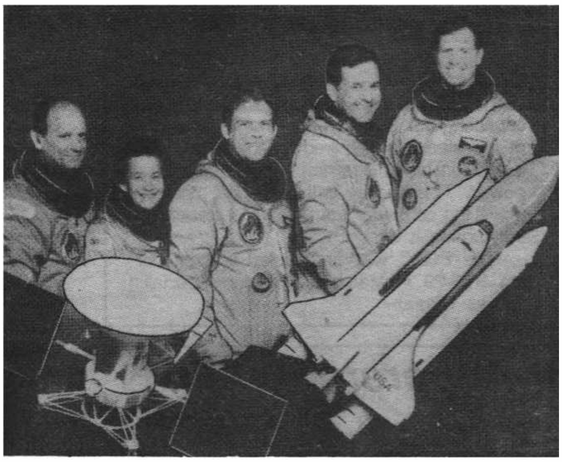
THE CREW

COMMANDER
David M. Walker (Captain USN)

Although born in Columbus, Georgia., Walker considers Eustis, Florida, his hometown. Walker is a member of the astronaut class of 1978.

Walker was pilot of STS 51-A, launched November 8, 1984, marking the second flight of the orbiter Discovery. During the mission, the crew deployed two satellites and in the first space salvage mission in history, also retrieved and returned to Earth the Palapa B-2 and Westar VI satellites.

His NASA assignments also have included: Astronaut Office safety officer; deputy chief of Aircraft Operations; STS-1 chase pilot; software verification at the Shuttle Avionics Integration Laboratory (SAIL); and assistant to the director, Flight Crew Operations. He has logged 192 hours in space prior to this flight.



The STS-30 crew: (Left to right) Mission Specialists Norman Thagard, Mary Cleave and Mark Lee. Pilot Ronald Grabe and Commander David Walker. *NASA*

PILOT
Ronald J. Grabe (Colonel USAF)

Grabe was born in New York and is a member of the astronaut class of 1981. Grabe was pilot for STS 51-J, the second Space Shuttle Department of Defense mission, launched October 3, 1985, on the orbiter Atlantis' maiden voyage. He has logged 98 hours in space prior to STS-30.

MISSION SPECIALIST 1
Mark C. Lee (Major USAF)

Lee was making his first space flight. Born in Viroqua, Wisconsin, he is a member of the astronaut class of 1984.

Lee has participated in the planning and simulation of several extravehicular activity missions and has served as the support crewmember for mission STS 51-I, Leasat retrieval and repair. He also has served as a capcom.

MISSION SPECIALIST 2
Norman E. Thagard (M.D.)

Although born in Marianna, Florida, Thagard considers Jacksonville, Florida his hometown. He is a member of the astronaut class of 1978.

Thagard was a mission specialist on STS-7, launched June 8, 1983. It was the second flight for the orbiter Challenger and the first mission with a five-person crew. During the mission, the STS-7 crew operated the Canadian-built remote manipulator system arm to perform the first deployment and retrieval exercise with the Shuttle Pallet Satellite (SPAS-01); conducted the first formation flying of the orbiter with a free-flying satellite (SPAS-01); and carried and operated the first US/German cooperative materials science payload. During the flight, Thagard conducted various medical tests and collected data on physiological changes associated with astronaut adaptation to space.

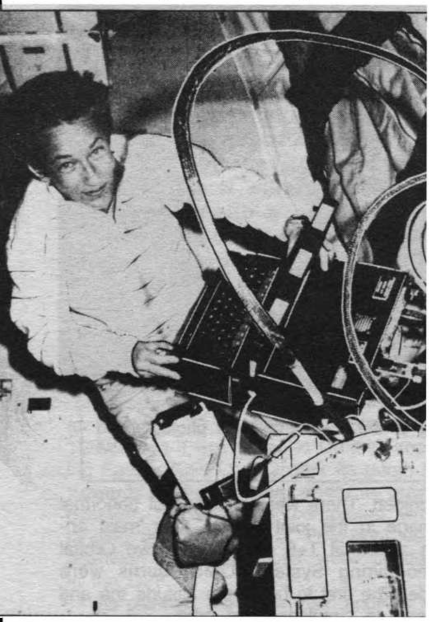
Thagard also served as a mission specialist on STS 51-B, the Spacelab-3 science mission, launched April 29, 1985, aboard Challenger. Duties on orbit included satellite deployment operation with the NUSAT satellite and care for the 24 rodents and two squirrel monkeys contained in the Research Animal Holding Facility.

MISSION SPECIALIST 3
Mary L. Cleave (Ph.D)

Cleave was born in Southampton New York. She is a member of the astronaut class of 1980.

Cleave was a mission specialist on STS 61-B which was launched at night, November 26, 1985. During the mission, the crew deployed communications satellites and conducted two 6-hour spacewalks to demonstrate Space Station construction techniques with the EASE/ACCESS experiments. This was the heaviest payload weight a Space Shuttle had carried to orbit. Cleave also has worked as a capsule communicator (capcom) in the Mission Control Center on five Space Shuttle flights. Cleave has logged 165 hours in space prior to this mission.

Lap-Top Computer Monitors Experiment



Mary Cleave operates the PGSC lap-top computer. *NASA*

The lap-top computer carried on STS-30 is an updated version of the Shuttle Portable Computer (SPoC) used on every Shuttle mission since STS-9. The new computer, called the Payload and General Support Computer (PGSC), brings the latest technology to the Shuttle's crew compartment. While the SPoC represents 1980 technology, the PGSC is 1988 state-of-the-art equipment.

On STS-30, the PGSC was used to gather data from a fluids crystal growth experiment, designated FEA-1 (see box below).

"The PGSC is really going to enhance our ability to do science on the middeck," said STS-30 Mission Specialist, Mary Cleave. "It will give us more of a chance to interact with experiments and prove further the value of having a person available to work with the payload. Right now most experiments are very automated."

The PGSC is ideal for monitoring and gathering information from payloads. The computer's floppy disks can be used to store payload data for analysis upon the Shuttle's return to Earth.

SPoC also offers a miniaturized version of the global tracking map that is the flight control room's central display; readouts of mission elapsed time; time to acquisition and loss of signal; and Greenwich Mean Time. On the portable computers flip-up display, the map shows current position, day and night cycles, Earth observation points and tracking coverage boundaries, both by satellite and ground stations. The portable computer also offers a back-up for calculating deorbit targets to be used only in a dire emergency and a complete loss of communications with the ground. The SPoC has become an essential part of Shuttle equipment - but the computer's 384k memory allows only these functions, plus a few other limited programs.

The PGSC, featuring a 20-megabyte hard disk, can run all the SPoC software with a tremendous amount of room spare for other programs, including word processing and possibly a computerised Flight Data File - a 25 book, 2,500 page file carried aboard the Shuttle that holds the vital information covering all aspects of a mission. In addition, the PGSC has a built-in 3.5 inch floppy disk drive that could revolutionize data gathering from payloads.

The PGSC has an eight megabyte Random Access Memory (RAM), about 16 times that of the SPoC. Despite its expanded capability the PGSC, on average, uses half of the electricity required by the SPoC, and it can run for at least ten minutes on battery power. This facility will allow the crew to move the computer from place to place without turning it off.

The PGSC was first tested in orbit during STS-29 in March by Mission Specialist James Bagian.

Fluids Experiment Apparatus (FEA)

The Fluids Experiment Apparatus (FEA), a multipurpose experiment support system developed by the Space Transportation Systems Division of Rockwell International, is designed to perform materials processing research in space. The result is convenient, low-cost access to space for basic and applied research in a variety of technologies.

The FEA is a modular, microgravity chemistry and physics laboratory used for the first time on STS-30 for materials processing research in crystal growth, general liquid chemistry, fluid physics, and thermodynamics. It has the functional capability to heat, cool, mix, stir, or centrifuge experiment samples that can be gaseous, liquid, or solid. Samples can be processed in a variety of containers or in a semicontainerless floating-zone mode. Multiple samples can be installed, removed, or exchanged during a mission through a 14.1-by 10-inch door in the FEA's cover. Instrumentation can measure the sample's temperature, pressure, viscosity, etc. A video or super-8-millimetre movie camera can be used to record sample behaviour. Experiment data can be recorded by a portable computer with floppy disk drive. This computer is also capable of controlling experiments. (see separate item on the Shuttle lap-top computer).

The FEA is mounted in place of a standard stowage locker in the mid-deck of the Shuttle crew compartment, where it is operated by the flight crew. Modular design permits the FEA to be easily configured for almost any experiment. Configurations can even be changed in orbit, so that experiments of different types can be performed on a given Shuttle mission. Optical subsystems can include custom furnace and oven designs, special sample containers, low-temperature air heaters, specimen centrifuge, special instrumentation, and other equipment specified by the user.

were completed the crew began to prepare for the deployment of Magellan. Deployment of an interplanetary spacecraft requires precision positioning. The orbiter's Inertial Measurement Unit (IMU) and the IMU onboard Magellan were precisely matched. Atlantis' star tracker was used to obtain navigational fixes to ensure the accuracy of the IMUs.

At T+5 hours 40 minutes the crew tilted Magellan and its IUS booster to 29 degrees. With the front of Magellan now outside the payload bay it was possible to test communications between the IUS/Magellan and ground station. After last minute checks of the probe and booster had been completed the crew were given a 'go' for deployment by Mission control. The IUS/Magellan combination was tilted to the deployment angle of 52 degrees and at T+6 hours 14 minutes 29 seconds Mission Specialist Mark Lee triggered powerful springs that sent the probe out of the payload bay.

Commander Walker began a series of RCS firings to distance Atlantis from the probe and then manoeuvred the spacecraft to observe Magellan's solar panel deployment. After the crew witnessed the successful opening of the solar panels Walker fired the OMS engines to increase the separation between the two craft. The final manoeuvre of the deployment sequence was to turn Atlantis' underside towards the probe to protect the orbiter's windows from the exhaust of the IUS booster.

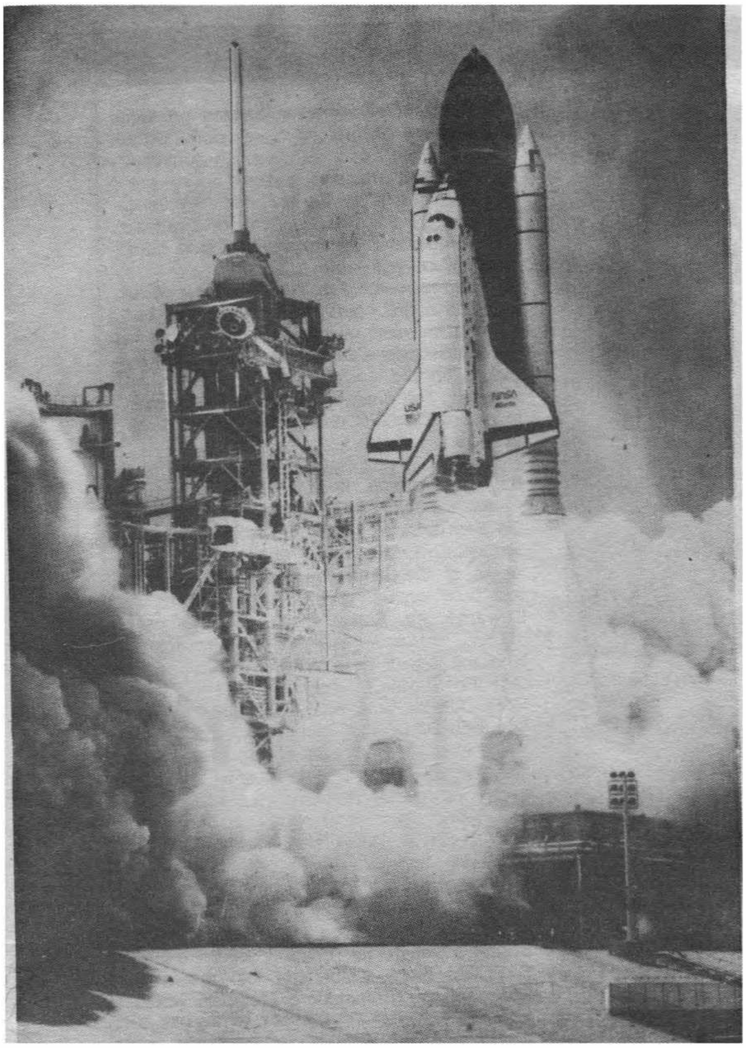
The IUS booster fired an hour later propelling Magellan on its 15 month trip to Venus.

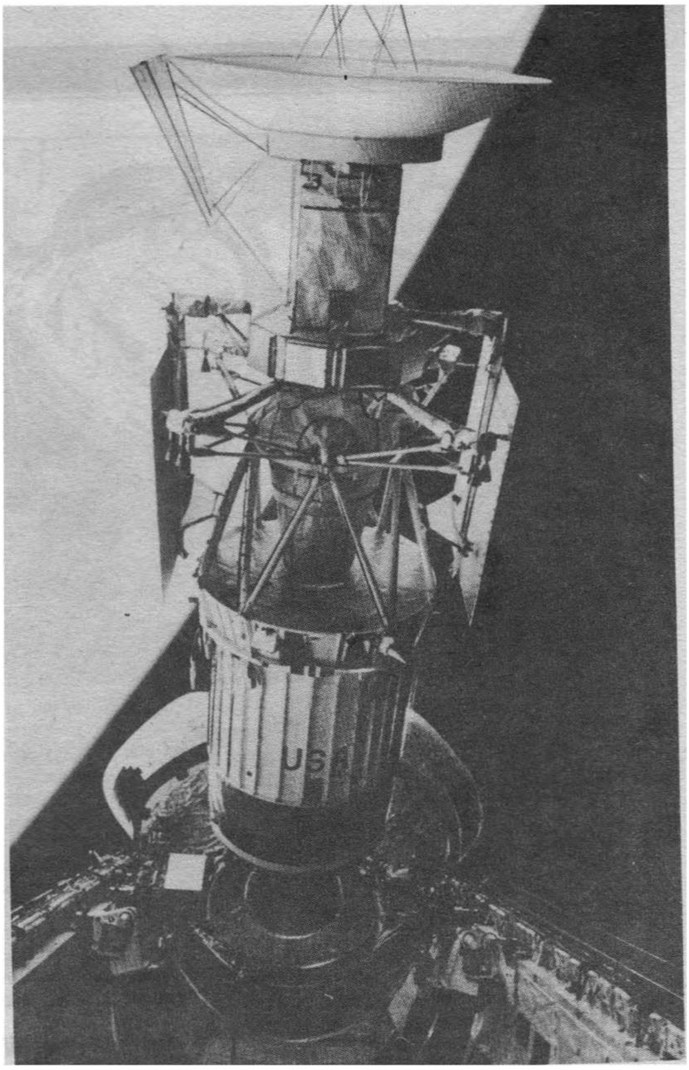
Day two: May 5, 1989

The STS-30 crew spent most of the second day in orbit on scientific experiments Television and 35mm cameras were utilised to study thunderstorm lightning activity over areas of Africa and South America as part of the Mesoscale Lightning Experiment (MLE). The Fluid Experiment Apparatus (FEA-2) was utilised to study the effects of the microgravity environment on materials processing. In addition as part of the AMOS experiment (see **Spaceflight,** May 1989, p.176 for a brief description of AMOS) Atlantis fired its Reaction Control System (RCS) jets while optical instruments on the ground at Maui, Hawaii observed their signatures.

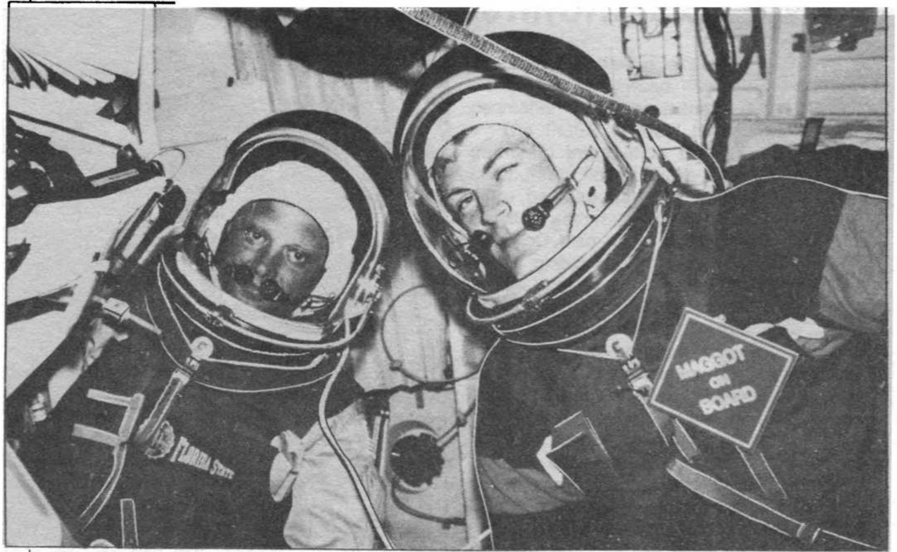
During the day the crew experienced difficulties with the Text and Graphics System (TAGS) which is designed to receive uplinked images and text from the ground. During the four day flight 400 images were to be transmitted via TAGS. However the system experienced several paper jams during operation. The non-invasive central venous pressure measuring system also failed on Day Two. The experiment was

(Top left) Atlantis blasts off from launch pad 39B at the Kennedy Space Center on May 4.
(Top right) The Magellan probe is released from its cradle in the payload bay.
(Bottom) The STS-30 crew pose on the orbiter flight deck. (left to right) Norman Thagard, Ronald Grabe, Mary Cleave, David Walker and Mark Lee. ***NASA***





STS-30 MISSION REPORT



Mission Specialists Norman Thagard (left) and Mark Lee evaluate the use of Launch Escape Suit Helmets for EVA pre-breathe operations. *NASA*

designed to investigate the shift in body fluids towards the head experienced by astronauts in weightlessness. During the day humidity in the crew cabin increased from the normal 30% to over 50%. The orbiter was realigned so its payload bay radiators were turned towards the cold of space and the humidity gradually decreased.

Day Three: May 6, 1989

The crew was awakened by Mission Control playing collections of the astronauts college songs over the communications system. The crew continued with their scientific experiments including lightning photographv, microgravity studies and further AMOS observations.

The crew tested a home-video 8mm camcorder as a cheap and possibly superior alternative to the existing orbiter television system. The camcorder was used to record the FEA experiment results. Commander Walker evaluated the use of the orbiter Heads Up Display (HUD) as a backup star sighting device for aligning the Inertial Measurement Unit (IMU).

During the day the shutter of a Hasselblad 70mm camera stuck and the crew was unable to repair it. A minor problem developed with the onboard water dispenser, used for the preparation of dehydrated meals. The dispenser would not deliver the required amount of water. By connecting a small piece of hose to the dispenser the crew were able to judge the amount of water injected into their food.

Day Four: May 7, 1989

The crew was awakened by mission control with the theme from the film "Rocky". Later the crew took part in an on-orbit press conference.

The crew continued work on the experiments but were interrupted when one of Atlantis' five General Purpose Computers (GPC) failed. Flight Director Ron Dittemore gave the crew permission to carry out the first on-orbit replacement of a GPC - even though it had recovered - to provide an extra measure of confidence during reentry. A spare GPC is carried in the orbiter middeck and Shuttle crews receive training on their replacement before each mission. Dittemore said the faulty GPC, which controlled the Shuttle's payload buses, never presented a threat to the mission. An initial analysis by the Johnson Space Center's Data Processing Section pointed to a hardware failure in the GPC.

The replacement of the GPC took about four and a half hours, with Cleave and Lee working between middeck lockers to get to the Shuttle avionics bay, the rest of the crew looking on and lending a helping hand when required. The 8mm video camera was used to record the GPC changeout for future reference

Day Five: May 8, 1989

Atlantis' two OMS engines were fired on the 64th orbit to begin the orbiter's reentry sequence. As the orbiter entered the upper layers of the atmosphere, Mission Control was busy evaluating the wind conditions at Edwards Air Force Base. Shuttle programme managers were hoping they could land the orbiter in crosswind conditions to test the Shuttle's tyres and steering systems. Atlantis was due to touch down on lake bed Runway 17 but cross wind conditions there had exceed safety limits Mission Control told Walker to change his landing to concrete Runway 22, where the crosswinds were lighter and almost ideal for the test NASA had in mind.

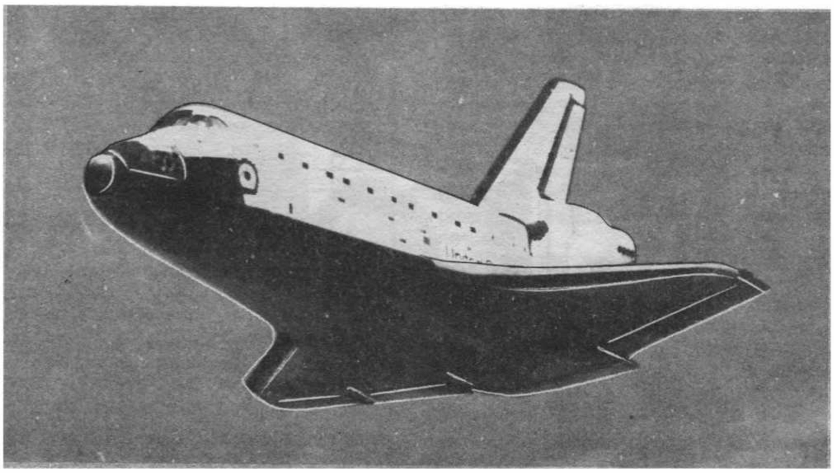
Walker brought Atlantis down to a perfect landing on the concrete runway, the orbiter's wheels coming to a stop at 12:44:33 PDT. "You've extended the Shuttle's reach far beyond Earth orbit," CAPCOM Frank Culbertson told the crew after landing. "Commodore Magellan would approve."

"Roger that," Walker said in return.

"The vehicle looks as clean as any one I've ever seen," said Richard Truly, the then Associate Administrator for Space Flight, now appointed NASA Administrator.

Atlantis has been returned to the Kennedy Space Center and work is underway to prepare her to launch the second interplanetary spacecraft of the year: the Galileo probe to Jupiter

(For further details of Magellan's voyage to Venus see Space at JPL starting on p.282.)



Atlantis glides towards a perfect landing at Edwards Air Force Base on May 8. *NASA*

STS-30 At a Glance

ORBITER: Atlantis (OV-104)
LAUNCHED: May 4, 1989 19·47 BST
LAUNCH SITE: Pad 39B, Kennedy Space Center, USA
LANDED: May 8, 1989 20:43:33 BST
LANDING SITE: Runway 22, Edwards Air Force Base, USA
LIFT-OFF WEIGHT: 4,525,116 pounds
LANDING WEIGHT: 192,313 pounds
APOGEE: 341 km
PERIGEE: 258 km
INCLINATION: 28.85 degrees
DURATION: 4 days 56 minutes 33 seconds
ORBITS: 64.5

COMMANDER: David M. Walker
PILOT: Ronald J. Grabe
MISSION SPECIALIST 1: Mark C. Lee (EV2)
MISSION SPECIALIST 2: Norman E. Thagard (EV1)
MISSION SPECIALIST 3: Mary L. Cleave

PRIMARY PAYLOAD: Magellan/IUS-18
SECONDARY PAYLOADS:
Fluids Experiment Apparatus (FEA)
Mesoscale Lightning Experiment (MLE)

Buran Steals the Show

Keith Wright

The arrival of the Buran space shuttle atop the world's largest aircraft, the Antonov An-225 Mriya (Dream), was the highlight of this year's Paris Air Show. The Mriya and Buran touched down on June 7, emerging from a stormy Paris sky to make a perfect landing on the 2,100 m long runway at Le Bourget Airport.

Buran's journey to Paris began on May 10 when the Antonov arrived at Baikonur to pick up its precious cargo. The Antonov team was not expecting to leave with Buran until May 25 at the earliest. But the operations went so well the number of test flights was reduced from nine to five and the crews found themselves six days ahead of schedule.

On May 19, with a combined weight of 560 tonnes, the Antonov and Buran took off from the Cosmodrome for the Soviet city of Kiev, where the spacecraft was given a thorough check and certified ready to continue. After a brief visit to Moscow the two craft returned to Borispol Airport, Kiev, where final loading of cargo and fuel took place.

Buran and the Antonov made the three and a half hour flight to Paris on June 7. As it entered French air space the Antonov was met by Mirage fighters of the French Air Force and escorted to Le Bourget airport, the air show venue. It made an impressive fly past above the runway before touching down at about 10:40am local time.

Buran seemed unaffected by the rain and turbulence it passed through before landing. US shuttle ferry flights are prohibited in such conditions - the impact of rain drops would damage the orbiter's protective tiles. However Buran's 38,000 quartz fibre tiles are apparently impervious to the rain.

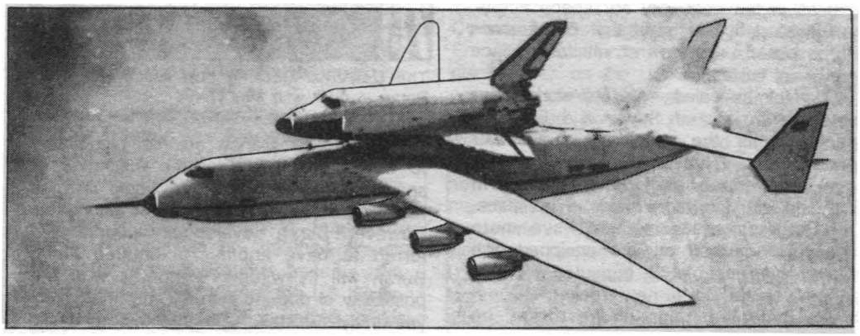
Paris Reports By Steven Young and Theo Pirard

Buran showed few signs of damage following her two orbit flight in November last year. The shuttle's lower surfaces looked pitted in places. The majority of Buran's scorched surfaces had been cleaned. A triangular shaped area along the fuselage and the tops of the payload bay doors seems to have been permanently discoloured. This area has a different type of tile, larger than those on the forward fuselage. Buran does not appear to have any heat insulation blankets, now used extensively by the US shuttle.

The lower surfaces of the RCS pods were blackened following the November mission. It is unclear if this was caused by reentry heating or burns of the RCS thrusters. What ever the cause, it seems the Soviets have decide to replace the original white tiles with black insulation. This work appeared incomplete, with tarnished tiles still in place.

Buran's Paris visit provided the first detailed view of the aft of the Shuttle where the Orbital Manoeuvring System (OMS) engines and triangular umbilical plate are located (see photograph). The entire aft bulkhead is heavily armoured with heat resistant tiles. There is a service hatch on the side of the aft fuselage to giving access to the interior. The Liquid Oxygen and Kerosene tanks for the OMS and RCS thrusters and the Auxiliary Power Units (APUs), which produce pressure for the orbiter's hydraulic systems, are located in this area. There are a number of vents around the aft fuselage possibly exhausts from the APUs and vents

Buran and the An-225 during test flights prior to the Paris visit. *Antonov Design Bureau*



for dumping OMS and RCS fuel

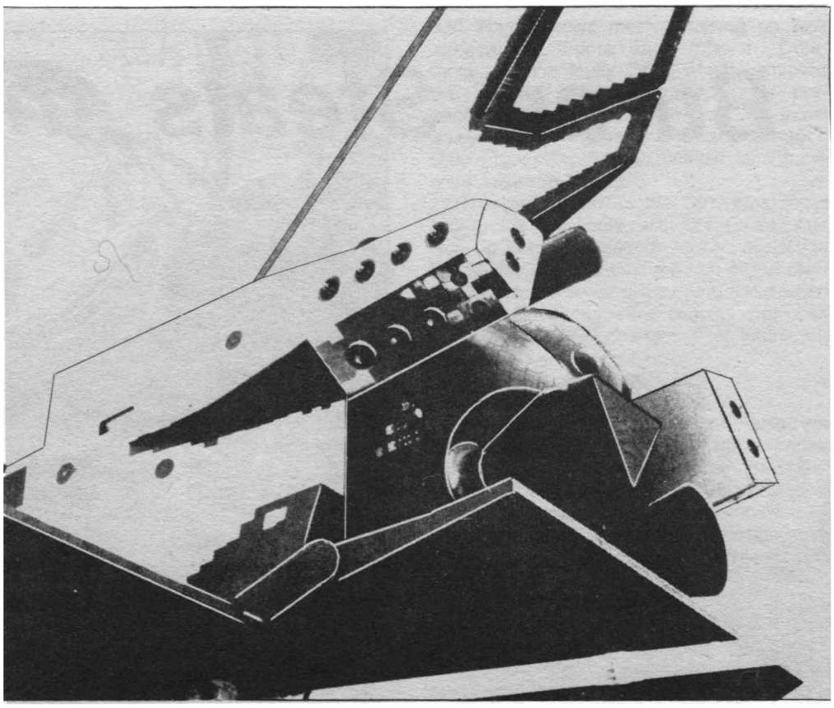
Four vent doors are spaced out along the Soviet orbiter's fuselage and appear to be of exactly the same design used in the US Shuttle. The vents are opened to depressurise the interior of the fuselage during the later stages of ascent and are closed for repressurisation during descent.

The orbiter's OMS and RCS nozzles had been plugged to prevent contamination of their motors The aft RCS primary thrusters are located in exactly the same positions as the US Shuttle's three thrusters on the upper and lower side of the pod and four on the outer side Also located on the lower side of the pod are two vernier thrusters, used for precise manoeuvres and station keeping operations Unlike the US shuttle there are no vernier motors in the forward RCS assembly.

Post-mission examination of Buran was interrupted by the visit to Paris and work will continue upon the shuttle's return. The fact space officials were willing to lose several weeks work while Buran was ferried to Paris indicates it will be some time before its second mission. Cosmonaut Yuri Romanenko has revealed Buran's cabin is undergoing a refit in preparation for a manned flight.

Spaceflight was invited aboard the Antonov for a tour of the massive aircraft, writes *Steven Young.*

The guide for the tour was Myria's navigator who had the day before plotted a course from Kiev to Paris. Three large charts in the cavernous cargo bay detailed various payloads the An-225 could carry. The third chart depicted the British Hotol space plane atop the Antonov. A study conducted by the Soviets reportedly shows it would be cheaper to fly Hotol on Myria to an equatorial launch site than it would for Hotol to fly under its own power.



The aft fuselage of Buran Note the damage to the underside of the RCS pod, the access hatch and triangular umbilical plate. *Keith Wright*

On the flight deck, sitting in the pilot's seat of the world's largest aircraft, I took the opportunity to question the Navigator.

I asked if the aircraft was difficult to fly with Buran attached. I was told the two craft handled better than expected. Was there any umbilical connections between the An-225 and Buran? No the shuttle was completely inert and required no monitoring during flight. The An-225 had been designed specifically to carry the Soviet shuttle but would have many other uses the Navigator explained.

Shatalov: 'Glavkosmos Must Take Control'

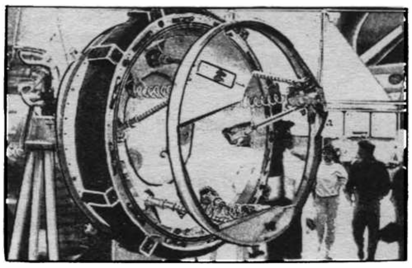
New Soyuz and Progress Spacecraft under Development

Cosmsonaut Training Chief Vladimir Shatalov, accompanied by seven cosmonauts, was a member of the Soviet delegation at the Paris Air show. During a brief interview Shatalov commented on his proposal to establish a Soviet space agency (see *Spaceflight,* July 1989, p.218):

"I criticized Glavkosmos in the hope the organisation would increase its influence in the management of Soviet space activities. Glavkosmos is a young organisation and does not control every element of our space programme. Through glasnost, we wish Glavkosmos will take a serious approach to organise in the best way our space efforts. By criticising it, we hope that Glavkosmos will become a good and efficient space agency in USSR."

Shatalov, revealed: "We are working on improved versions of Soyuz and Progress spacecraft for the utilisation of the Mir space station. The Soyuz spacecraft will have large capacities for manoeuvring in orbit and carrying more payload in space. The Progress spacecraft will have more capacity of payload and be equipped with recoverable/reusable capsules. The launch vehicle, is a new rocket." Questioned about the name of the rocket, he replied: "I have no comment about this name. Zenit, was invented by another team in USSR and I am not frankly responsible for invention of the name!"

About Buran and possible use with the Mir station: "We are not pressed to use this vehicle. Space planes are complementary to Soyuz spacecraft for the utilisation of space station elements. We would like the next flight to be manned and not automated. However, Buran development people preferred to have another automated flight. Buran will fly within 18 months with the possibility of docking with Mir, but that is not yet firmly decided... Six months after this automated mission, cosmonauts will fly aboard Buran."



The Universal Docking Port which will allow Buran to dock with Mir.
James Goddard, Science Museum

Shatalov went on to say: We are at a crucial point in manned space flight we must explore the acquired know-how and to go ahead with new investigations for the future. There are possibilities of industrial production in space.

Dr. Alexander A. Serebrov, pilot-cosmonaut named for the next Soyuz TM mission in the Mir-Kvant complex, described the next two modules to be launched before the end of this year: "The first module to be launched in September-October will increase the living quarters and experiment opportunities with the Mir station; a special airlock will allow EVA and the use of a space scooter [Manned Manoeuvring Unit]."

"A second module will be launched in December-January and will be equipped with a universal docking port [this port, similar to the androgynous docking system tested during the ASTP mission, was exhibited at the USSR pavilion] and with industrial production facilities; these facilities will consist of optical heating, of fluid physics, electronics and metallurgy production in vacuum, electrophoresis." He said that Buran would be equipped with an androgynous ASTP-type docking system.

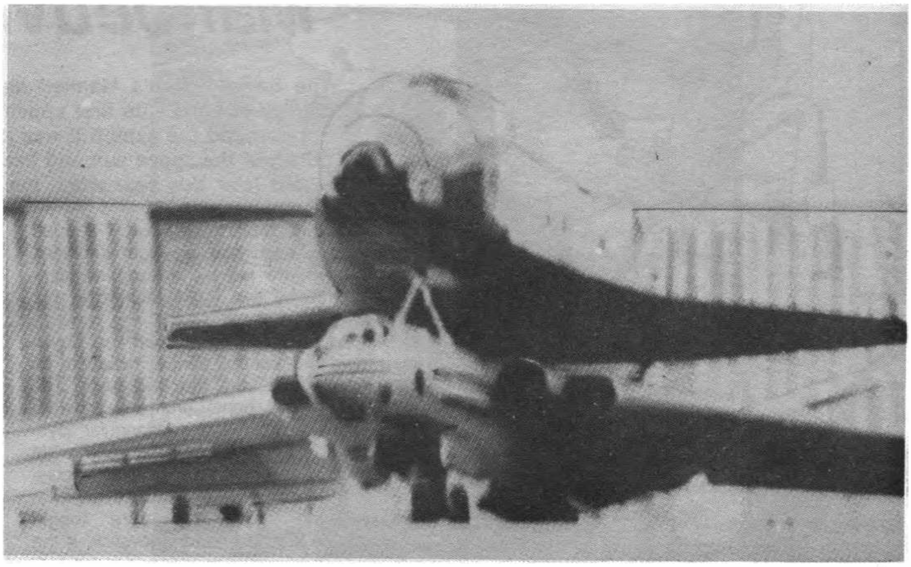
Antonov Dream Solves Shuttle Transport Nightmare

The Antonov An-225 Mriya (Dream) has eased the problem of transporting shuttle orbiter airframes a distance of more than 2,000 km from a factory near Moscow to the Baikonur Cosmodrome in Kazakhstan.

The Soviet orbiters are manufactured by the Molniya Scientific and Industrial Enterprise at its Tushino Machine Building Factory near Moscow. From the factory Buran had to make the 2,000 km trip to Baikonur without its vertical stabilizer and with many of its heat resistant tiles missing. The orbiter could not be transported in its completed form because the 60 tonne craft was too heavy for conventional aircraft. A Myasishchev M-4 bomber was adapted to carry the stripped-down orbiter. The bomber's fuselage was lengthened and reinforced and its vertical stabiliser replaced by two stabilisers mounted on struts either side of the rear fuselage.

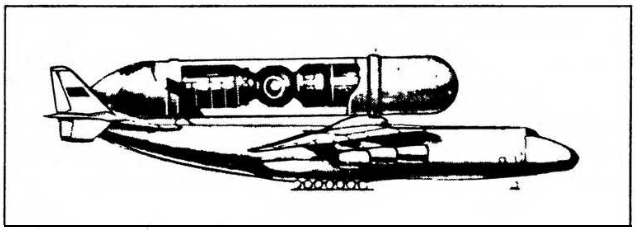
Buran was transported from the factory to the airport by road and then by barge. For the entire journey the orbiter was protected from prying eyes by sheets of tarpaulin. At the airfield a large mobile crane placed the orbiter atop the M-4 bomber. A tail cone was was used to protect the carrier aircraft from turbulence. The Soviets said the two craft had excellent aerodynamic qualities.

When Buran arrived at Baikonur it was lifted from the aircraft by a crane similar to the US Shuttle's Mate-Demate device and transported to the Assembly and Testing Plant (ATP), where final work was completed.

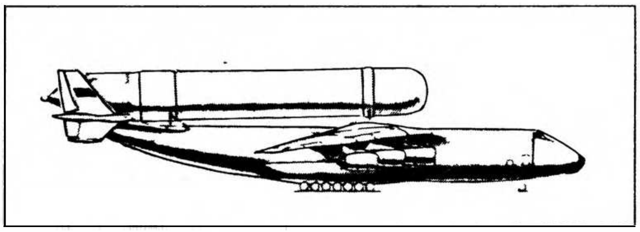


An M-4 bomber takes off with the partially assembled Buran.

The An-225 will make it possible to transport completed orbiters from the factory to Baikonur. Another important task will be to return the shuttle from a contingency landing site in the event of an emergency landing. The Antonov Mriya will also carry parts for the Energia booster. Both the core stage and strap-on boosters can be carried externally.



The An-225 carries a future space station module.
Antonov Design Bureau



The Energia core stage can be accommodated atop the An-225
Antonov Design Bureau

CNES to Start Talks on Third Franco-Soviet Mission

The French space agency, CNES, has agreed to negotiate terms with Glavkosmos for a third Soviet-French manned space mission, this time on a commercial basis.

French cosmonaut Jean-Loup Chretien has made two flights aboard Soviet spacecraft, the first to Salyut 7 in June 1982 and the latest being a month long stay onboard the Mir space station last November. The French made no payment for the two missions. The French announced last year they planned to fly a joint mission with the Soviets - on a non-commercial basis - every two years. But the commercial arm of the Soviet space programme, Glavkosmos, insisted they pay for their next flight. After much resistance the French have agreed to the Soviet terms. European independent access to space with Hermes will not be available until the end of the next decade and the Space Shuttle is to carry few 'passenger astronauts'

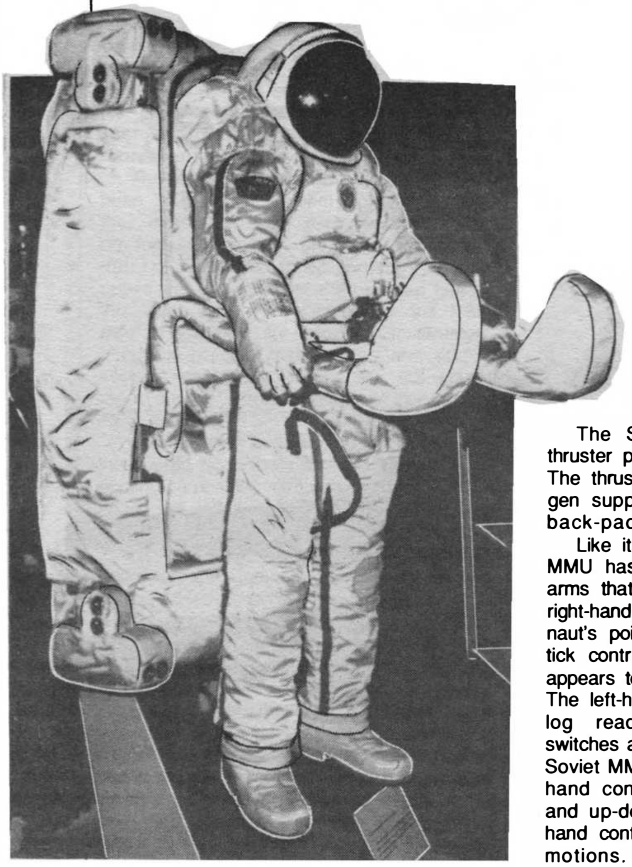
CNES hopes to reduce the fee of $10-12 milion by offering the Soviets use of any French equipment left aboard the station. The Austrians have already come to a similar agreement.

Michel Tognini, back-up to Jean-Loup Chretien, is tipped to be the third French cosmonaut (Patrick Baudry became the second when he flew aboard the US Space Shuttle). Two back-ups are expected to be trained along side Tognini.

Soviets Offer to Launch US Space Station

The Soviet Union has offered to launch the US Space Station Freedom with its Energia heavy lift booster.

William Wirin of the Glavkosmos-Space Commerce Corporation told ***Spaceflight*** Energia could launch Freedom cheaper and quicker than on the US Shuttle or the proposed Shuttle-C. However he admitted, for political and prestige reasons, the offer would not be accepted. He said the proposal would serve its purpose by drawing attention to the Soviet Union's space capabilities. Wirin said he believed US Government restrictions on the use of Soviet space services would increase. He said US companies could avoid the problems of technology transfer by leasing Soviet satellites. A Gorizont communications satellite can be leased for $1.5 million per anum.



Soviet Union Exhibits Manned Manoeuvring Unit

The Soviet Union's Manned Manoeuvring Unit (MMU) was on display in Paris - its first appearance in the West. With no barriers around the exhibit it was possible to make a close examination of the space suit and back-pack, which is expected to be tested later this year when manned Mir operations resume.

The Soviet MMU has four T-shaped thruster pods each housing eight thrusters. The thrusters are fed by pressurised nitrogen supplied by two tanks located in the back-pack.

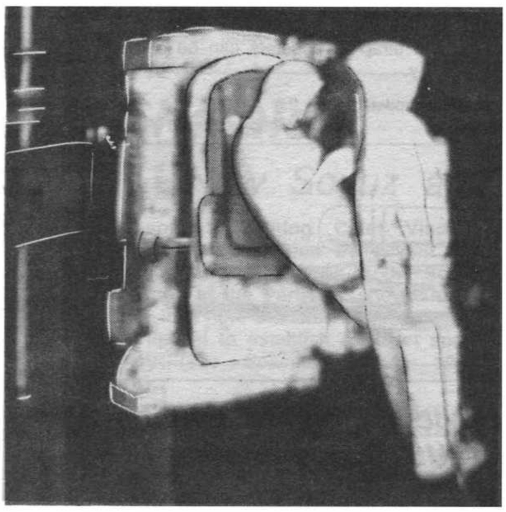
Like its American counterpart the Soviet MMU has two control panels mounted on arms that extend from the back-pack. The right-hand control panel (from the cosmonaut's point of view) has a triangular joystick control, six toggle switches and what appears to be a small liquid crystal display. The left-hand control panel carries an analog read-out instrument, more toggle switches and a round headed joystick. If the Soviet MMU follows the US design, the left-hand controller governs fore-aft, right-left and up-down movements, while the right-hand controller handles roll, pitch and yaw motions.

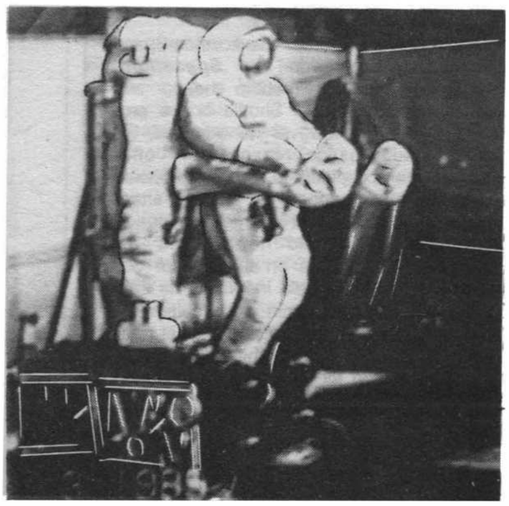
The Soviet MMU is larger and more bulky than the US version, extending from the helmet to below the knees. Unlike the American MMU, which has a metal skin, the Soviet MMU is protected by a layer of thermal blankets. The blankets can be peeled back exposing the MMU interior to allow easy on-orbit maintenance.

A video film in the Soviet Pavilion showed cosmonauts training to use the MMU. The cosmonaut enters the space suit in the normal way, climbing through the back of the suit. Once the seal between the hatch and the suit is made, the MMU control arms are raised into the correct position and the cosmonaut is ready to begin training.

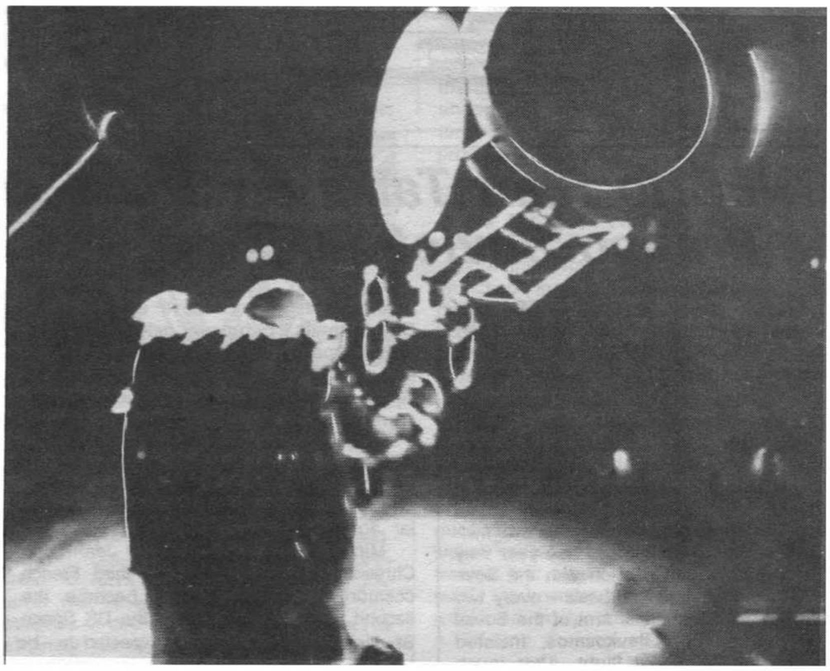
For training purposes the MMU is mounted to what appears to be a hover pad, which lifts the cosmonaut and his MMU fractionally off the ground on a cushion of air. By using the hand controls the cosmonaut can manoeuvre the MMU on the polished floor.

The film sequence showed a cosmonaut approaching a mock-up of the one metre diameter airlock of the new Mir module. A grapple unit on his space suit (not on the suit at Paris) is then used to anchor the cosmonaut to the module. A similar grapple unit was used by the Americans to capture Solar Max during a 1984 Shuttle spacewalk





(Top left) The Soviet MMU as it appeared in Paris (Middle left) A cosmonaut climbs into the space suit with the MMU attached. (Bottom left) Mounted on a hover pad an cosmonaut can train to operate the MMU (Below) A cosmonaut using the MMU simulator approaches a mock-up of the one metre diameter airlock of the new Mir module



Pegasus Set for August 22 Launch

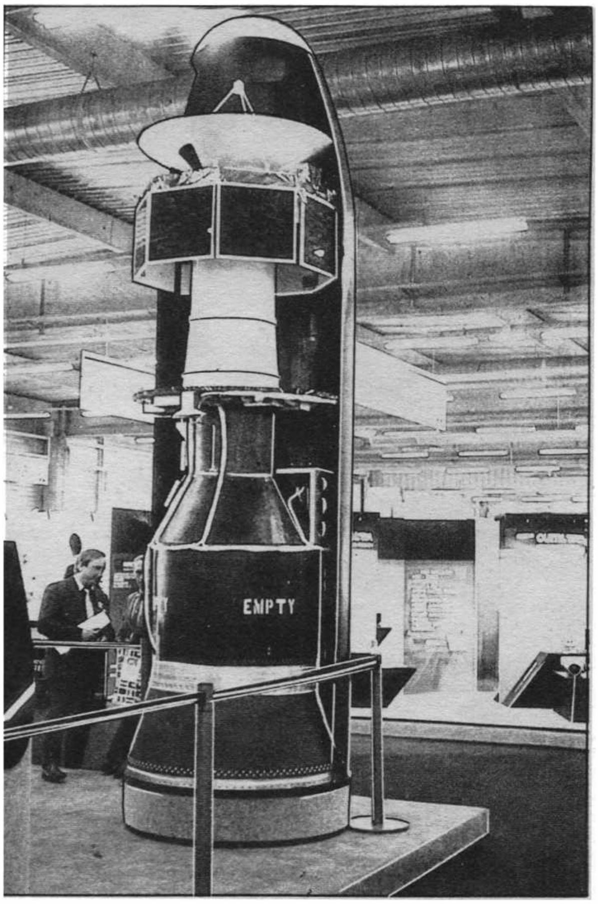
The Pegasus air launched booster is to orbit its first satellite on August 22, Bill Saavedra of the Orbital Sciences Corporation (OSC) told *Spaceflight*. After release from a NASA B-52 aircraft, Pegasus will ignite the first of its three solid rocket motors to place a NASA/Defense Advanced Research Projects Agency (DARPA) payload into Low Earth Orbit.

Preparations for the first launch have proceeded well: The Pegasus stages have undergone test firings on the ground and in July a Pegasus vehicle is to make two captive flights attached to the B-52. Once all these tasks are accomplished the way will be clear for the first launch.

OSC and Hercules Aerospace, the developers of this ingenious launch vehicle, hope Pegasus will promote the growth of light-weight satellites. Ball Aerospace is developing a series of so-called 'lightsats' that can be carried by the Pegasus. The booster is capable of delivering payloads weighing up to 900lb into Low Earth Orbits and carrying payloads of 1,500 lb on suborbital missions.

The Pegasus booster offers relatively cheap access to space, each launch costing about $6-7 million. OSC and Hercules are capable of manufacturing one Pegasus vehicle per month. If the launcher attracts a sufficient number of customers OSC and Hercules will expand their assembly lines to meet the demand. There is very little restriction on the actual launch rate, apart from the availability of the launch vehicles and a suitable carrier aircraft.

According to Mr Saavedra, one of Pegasus' many qualities is the ability to launch almost anywhere in the world. But to allow precise tracking of the vehicle's ascent, the first Pegasus launches will take place within existing launch ranges (in the case of the first flight Vandenberg Air Force Base will be used). Mr Saavedra singled out Kourou, conveniently positioned close to the equator, as one possible launch zone equipped with adequate tracking facilities. To make Pegasus completely independent from ground tracking support, a second aircraft could be fitted with the necessary tracking equipment he added. OSC and Hercules is also looking for a new carrier aircraft as the aging NASA B-52 aircraft will not always be available for their use.



A full scale mock-up of the Pegasus payload fairing with a Ball Aerospace communications satellite
James Goddard, Science Museum

Another feature of Pegasus is its simplicity. The final Pegasus assembly requires just six people and takes place on the back of a specially designed truck. The same truck is then used to transport the vehicle to the aircraft and lift it into position. The Pegasus deployment is controlled by a small console onboard the B-52. An Inertial Measurement Unit (IMU) inside the aircraft is used to update Pegasus' own onboard IMU with the aircraft's exact position. To further increase accuracy, OSC and Hercules plan to install a Global Positioning System receiver onboard the B-52 and eventually inside the booster itself.

If the first launch goes well a second Pegasus could be launched before the end of the year.

Ariane Recoverable Capsule Proposed

The West Germany company MAN Technologie is proposing a retrievable payload capsule for launch in the 1990s by an Ariane 4 or 5. The capsule would carry microgravity experiments into orbit for up to three weeks before returning them to Earth for analysis.

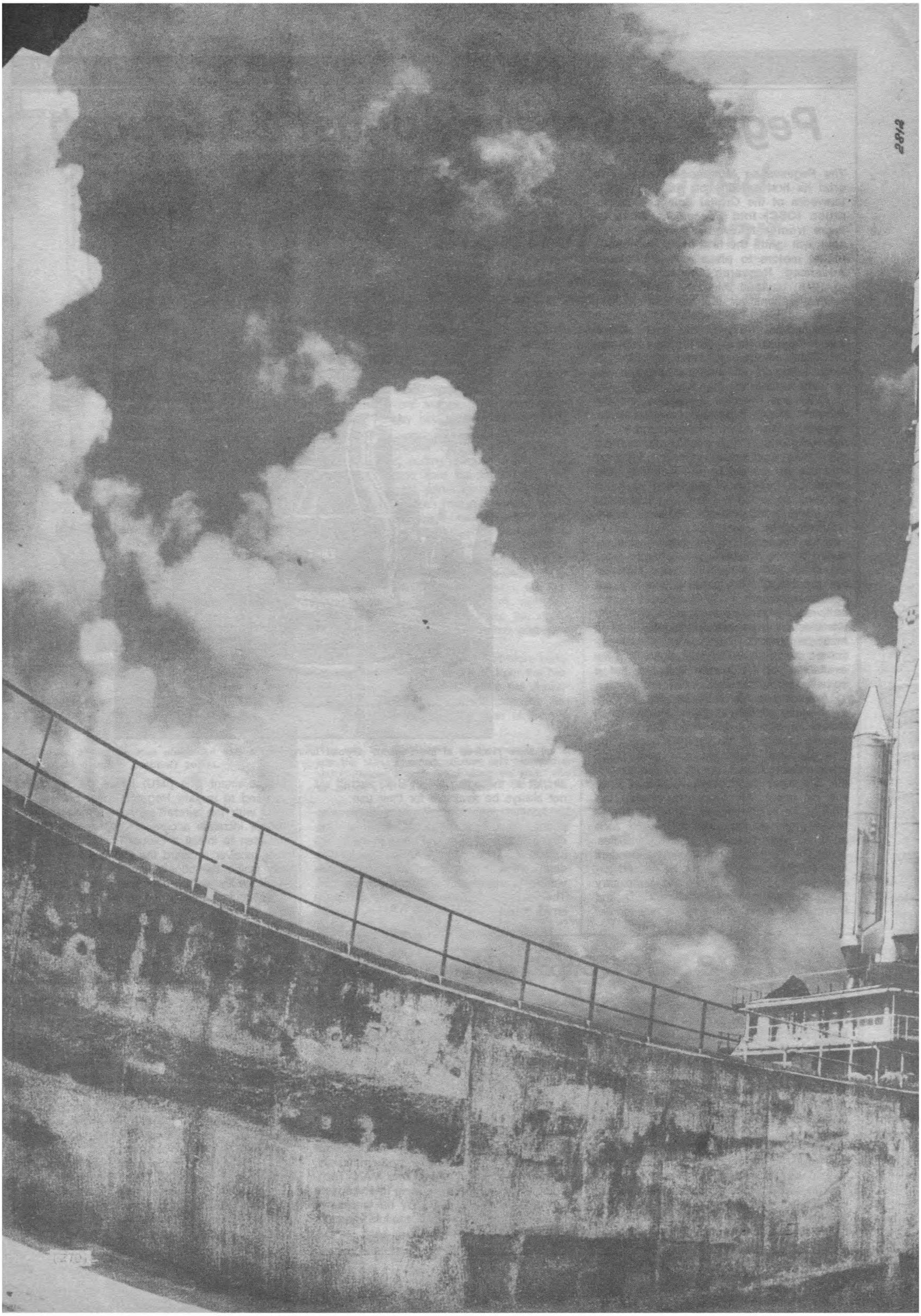
MAN Technologie believes its Ariane Capsule will close a gap in European space capabilities. Europe has had to rely on Soviet and Chinese recoverable capsules or the US Space Shuttle to carry microgravity experiments and return them to Earth.

The capsule has the same shape as the US Apollo Command Module but is slightly smaller. The capsule consists of two elements, the payload module (lower part) and the service module (upper part). The payload module is pressurised and can carry experiments weighing 400-900 kg. The spacecraft is powered by batteries and four solar panels mounted to the underside of the payload module. The service module contains the capsule's propulsion systems, parachutes for splashdown and a container where any last minute small payloads can be installed.

The capsule would be manufactured with existing techniques and materials, keeping production costs low. MAN Technologie investigated reusing the capsule but determined it would only be feasible to reuse part of the service module structure and equipment.

After completing a mission of 7-21 days the capsule is deorbited by firing its hydrazine fuelled main engine. During reentry the capsule is protected by an ablative heat shield 40mm thick in places. At the correct altitude the spacecraft's parachutes open and the capsule splashes down in the sea about 400km from the Kourou launch site. After recovery by ship the payload is transported back to Europe where the payloads returned to the investigators.

The Ariane Capsule study was financed by MAN Technologie. The French Space Agency, CNES, has supported the project from its inception and a proposal to implement the project is now with the German Ministry of Research and Technology.



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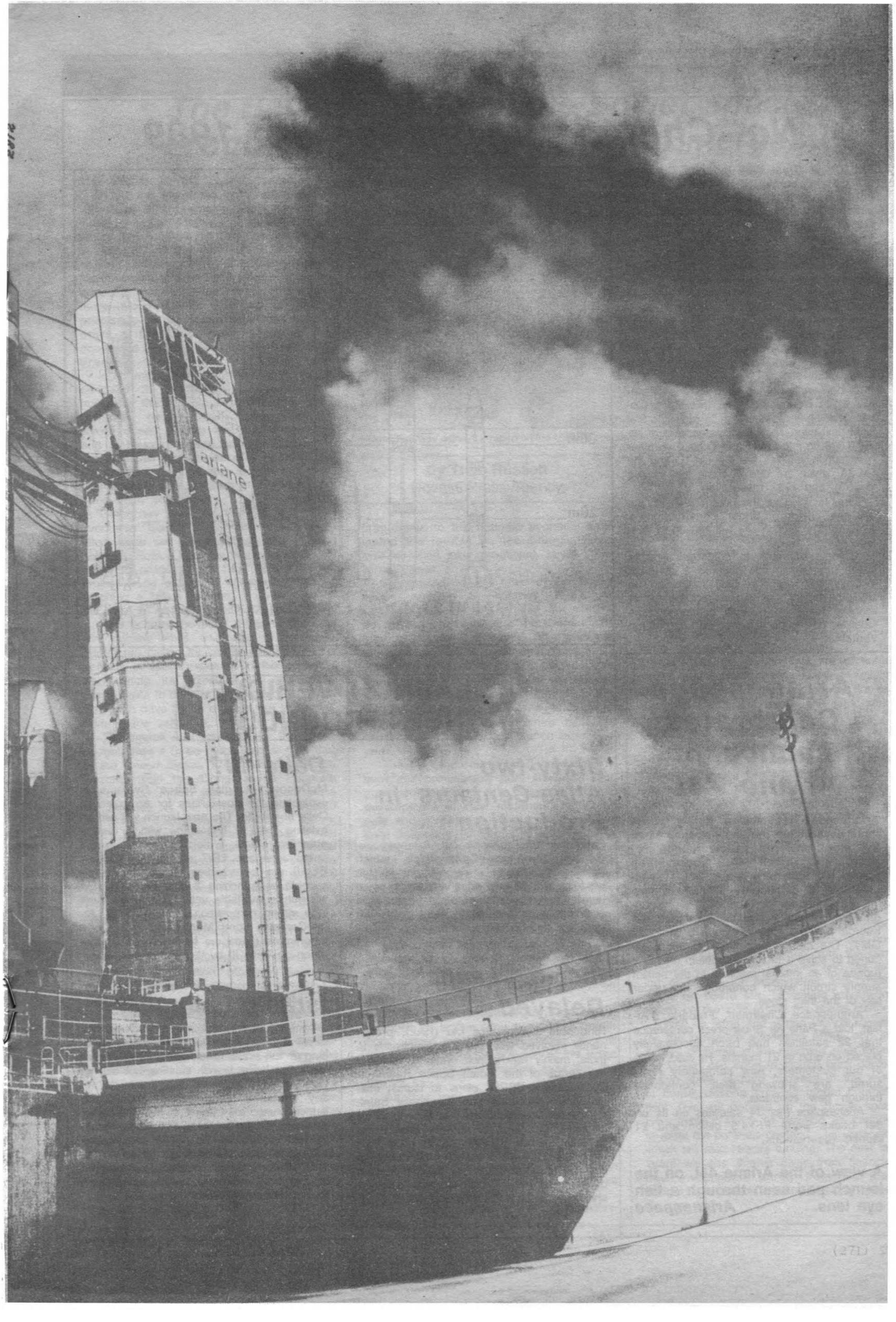
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No Chinese Launches in 1989

The China Great Wall Industry Corporation (GWIC) continued its efforts to market the Long March launch vehicle at this year's Paris Air Show. However Mr Luo Ge of the GWIC marketing department told *Spaceflight* China has no plans to launch any satellites this year.

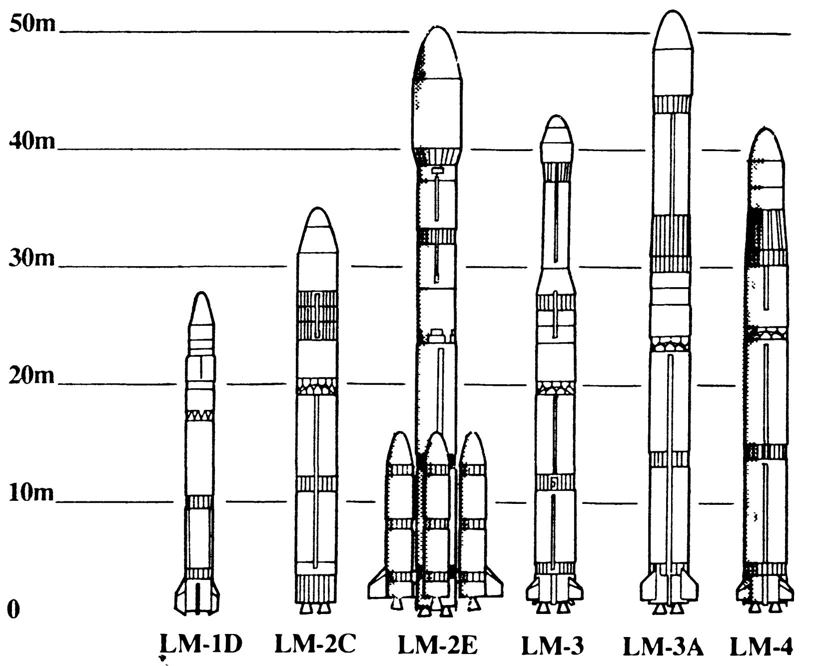
Mr Luo was unwilling to explain why there would be no launches this year, however, he did say launches would resume in 1990. China has launched at least one satellite per year since 1981 and in 1988 achieved four successful launches. Mr Luo went on to say the launch of three Western satellites by Long March would not take place until 1991.

A new variant of the Long March, the LM-2E, which is equipped with four liquid propellant strap-on boosters, is to make its first flight next year. The LM-2E is capable of lifting 8,800 kg into Low Earth Orbit. Two other new launch vehicles are the LM-1D and the LM-3A, which are due to come into service in 1991 and 1992 respectively.

New facilities for the Long March 2E and 3A are currently under construction at Xichang. The launch site will see up to three launches in 1990.

China's attempts to commercialise its space programme has suffered a set back following the recent troubles in China. The US government has suspended the export licenses for three US-built communications satellites due to be launched on Long March vehicles.

The Chinese Long March Family



Arianespace Celebrates Launch of Ariane 44L

Arianespace received a timely boost three days before the show opened when the most powerful Ariane launch vehicle, the Ariane 44L successfully placed the Superbird A and DFS-1 satellites into Geostationary Transfer Orbit.

The launcher - equipped with four strap-on liquid boosters - blasted off from the Kourou Space Centre on June 5 at 22:37 GMT. The launch had been earlier postponed to solve a technical problem due to a rupture of an internal manifold in the helium supply circuit which conditions the upper bay of the third stage.

Arianespace Chairman, Frederic d'Allest, told a Paris Air Show press conference that 22 satellites had been successfully placed on orbit in 21 months. He said: "80% of our customers, now completely reassured, are showing their confidence through new contracts."

Arianespace has 34 satellites on its order books worth FF14.5 billion and 21 launch reservations.

A view of the Ariane 44L on the launch pad seen through a fish eye lens. ***Arianespace***

LAUNCH VEHICLE NEWS ROUNDUP

Sixty-two Atlas-Centaurs in Production

Following the example of Arianespace, General Dynamics Commercial Launch Services has made a commitment for the production of 62 new Atlas vehicles to cover launch requirements for eight years. It is planning to achieve up to eight flights per year, for $55-59 million each.

Indian Launches Delayed

Hindustan Aeronautics Ltd (HAL), prominently involved with the space activities in India, mainly with launch systems, revealed the status of the Indian Space Research Organisations (ISRO) plans to launch indigenously spacecraft. The Augmental Satellite Launch Vehicle (ASLV) is scheduled for its third test flight in mid-90. First Polar Satellite Launch Vehicle (PSLV) rocket will fly in mid-91. HAL is initiating the design of the 2nd stage structure for liquid propellant of the next Indian launcher, the Geosynchronous Satellite Launch Vehicle (GSLV).

Delta III?

McDonnell Douglas Space Systems is evaluating the possibilities for an improved Delta III vehicle. The new launch will use an existing Delta II first stage with a restartable 2nd stage. Which engine? It is still open: Japanese LE-7 of Pratt & Whitney RL-10 are possibilities. Delta III will be capable of launching 3 tons into GTO but will not be available until 1993, when it will face strong competition from Ariane 4, Atlas-Centaur, Long March and H-II. Delta programme managers have to make a decision on Delta III by the end of this year.

Israeli Launcher

Israel Aircraft Industries (IAI) were exhibiting a full-scale mock-up of Offek-1, Israel's first home launch satellite, but did not give any detailed information about the launcher used for Offek-1 or even its name. However, it was revealed that Israeli industry was working on the AMOS communications satellite to be launched by an Ariane 4 in 1993. Israel is apparently working on an improved rocket to launch satellites in geosynchronous orbit.

The Balance Sheet of the Soviet Space Programme: A Clearer Picture Emerges

The debate in the Soviet Union over spending on the space programme is in full flow, with some - such as Boris Yeltsin - calling for cuts of 40 per cent in space expenditure to finance social investments. At the same time, the continuing advance of Glasnost (openness), which is now spilling over into the space programme, has meant that much more information is emerging to give a precise picture of the size and breakdown of the space budget, and of the economic spin-offs from the programme.

Nicolai Ryzhkov delivers a report on the USSR's economic future. President Gorbachev looks on *Novosti*

By Theo Russell
Novosti Press Agency

In his major speech to the new Congress on May 30, President Gorbachev announced that "outlays on space programmes have already been partially scaled down," adding that further cost-cutting measures "should be found". An example of this was the decision to leave the Mir station unmanned from April of this year, until the two new modules to be added on have been completed.

Gorbachev went on to point out, however, that "thanks to the newest space-related ideas we are acquiring unique technologies. Suffice it to say that newest developments produced as part of the Buran project alone can yield substantial returns, reaching a billion roubles, if given over to the national economy and for export."

This echoes the main thrust of the current debate: while advocates of economic reform are calling for better utilisation of the benefits of space research in the economy as a whole, the scientists and technicians are at pains to point out the economic benefits which have been, or soon are to be, felt from space research.

The figures now emerging for the space budget show it to be much smaller than that of the United States. Prime Minister Nicolai Ryzhkov told the Congress of People's Deputies on June 7 that spending on space programmes for the current year amounted to Roubles 6.9 billion, of which 3.9 billion, or 56 per cent, is defence-related. A few days later the Soviet Chief of Staff General Mikhail Moiseyev wrote in *Pravda* that this compared with a US space budget of $29.6 billion, while America's spending on military space programmes was $22.8 billion - six times the equivalent Soviet figure. The comparison for spending on economic and space research was R1.7 billion and $3 billion, and for re-usable space systems R1.3 billion and $3.8 billion. Moiseyev said that the space budget accounted for almost 1.5 per cent of the USSR's total budget.

Detailed figures have also emerged recently allowing comparisons to be made in the cost of the two main thrusts of the Soviet Union's near-Earth space activity - the Mir station and the Energia-Buran system - which reveal that the latter has eaten up a far greater share of resources. Over a period of 13 years the cost of developing the massive Energia booster and the reusable shuttle has totalled R14 billion, according to the Minister of General Machine Building, Vitaly Doghuzhiyev. Doghuzhiyev, writing in the *Government Herald* while the Council of Ministers was debating the scientific and technological benefits of the space programme to the national economy estimated the returns on the Energia-Buran system, when fully operational, at R4-5 billion per year.

By comparison, the head of the Soviet space agency Glavkosmos Alexander Dunayev revealed in May that the cost of developing and operating the Mir station, from its launch in February 1986 until the return to Earth of its latest crew on April 27, amounted to a mere R1,471 million. This figure covers the entire cost of the station, the Kvant astrophysical module, the Gamma observatory, all crew and cargo delivery craft, and the two new modules which are scheduled for launch later this year.

The Soviet economy has indeed already benefitted considerably from its space programme in terms of data collection and the development of new materials, technologies and processes, although the precise level financially is difficult to quantify. According to General Moiseyev, "the use of space equipment in the Soviet economy has already yielded a conventional economic effect of more than 12 billion roubles." He went on to claim that "expenses on space equipment, if maintained at the present level, will be fully reimbursed by 1995."

One specific estimate given by Moiseyev is the use of meteorological satellite data in the Soviet economy, resulting in savings of 500 to 700 million roubles annually.

Detailed assessment of some 64 million hectares of arable land have been made from aboard the Mir space station, as well as observations of the pollution of the Volga River, the Black and Caspian seas and the Sea of Azov.

Another area of particular success is that of space photography, in which the USSR has now entered the world market in earnest. Soviet satellite pictures have already been sold to 200 foreign customers in 12 countries, and have been described in the US journal *Aerospace Technology* as the most accurate available.

Some 600 original scientific and technical inventions arising from the Energia-Buran programme have been made available for use in the economy, including new technologies and materials, machines, scientific equipment, programmes, and automatic control systems. Many of these have already been tested in various branches of industry, according to Vitaly Doghuzhiyev.

But questions remain as to how and when these spin-offs will actually translate into improved industrial performance. Mikhail Gorbachev told the Congress of Peoples Deputies that proposals for giving the new developments over to the economy were represented "in two volumes" to the Defence Council and to "dozens" of enterprises and economic organisations. Only if they were used in the economy and for export, he said, "will our space-exploration expenditures be justified.

It is also intended to use Buran to carry out servicing of satellites already in orbit, which could increase their service life from between 2 and 3 years to between 5 and 7 years or even longer. But with a manned launch of Buran not expected until 1991 at the earliest, it will be some years before the returns on the massive investment in the shuttle scheme will be felt.

As a result of the political pressures for space investment to show returns, combined with the current economic liberalisation and cost-accounting drive in the Soviet Union, various innovative approaches to obtaining a return on space expenditure through selling services abroad are now being adopted. These range from the commercial launching of satellites and the selling of places for experiments and cosmonauts on board Mir, to selling advertising space on the side of the Mir space station.

With its large and varied launch capability, the continued expansion of Mir and the advent of Buran in the relatively near future, the USSR can hope to plough back considerable sums of hard currency in the years to come, despite growing global competition. This will depend on the Soviet space programme's ability to develop its capacity to meet the potential demand - an expansion which will also require funding. The next few years will see a shift away from financing new investments purely from the state budget to a space industry seeking to pay its own way.

CORRESPONDENCE

Soviet Space Programme

Unknown and unconfirmed details of the Soviet Space Programme are the subject of recent correspondence to ***Spaceflight.***

More to be Revealed by Glasnost

Sir, On April 21, 1989, Cosmonaut Valentin Lebedev visited Texas A & M University in support of his book, *Diary of a Cosmonaut.* I was able to question him about the Zond lunar programme of the 1960's and 70's. During this discussion, I showed the Cosmonaut a drawing of the G-1-e heavy lunar booster, based upon the conical first-staged diagram by Charles Vick, and inquired as to the accuracy of the sketch. Cosmonaut Lebedev replied that the rendition was accurate. Additionally, I asked if the three reported failures of this rocket, reported as July 1969, June 1971 and November 1972 were correct, and received another affirmative answer.

I then inquired as to the Soviet designation for the booster and its name. Mr. Lebedev said that the booster was known as the "N" class, and that its nickname was "Carrier", but that it had no official name. He further commented that "we had a great deal of trouble with that one", in relation to the rocket. I believe the lack of an official name was due to its inability to successfully launch a payload.

When I showed Mr. Lebedev photocopies of Soyuz descent and orbital module-based lunar lander diagrams drawn by D.R. Woods, he immediately began to deny the existence of a Soviet manned lunar landing programme in the 1960's, calling it a "fantasy". He also stated that no cosmonauts had been trained for lunar landing.

Consulting with James Oberg, I learned that there have been no prior admissions of the existence of such a lunar booster by Soviet officials, and that this should be considered the first confirmation of the existence of manned lunar landing-related hardware. It is my hope that Glasnost will reveal more of this program, which still continues to be hidden from Western knowledge.

MARK CAMP
Texas, USA

Soviet Mini-Shuttle Doubts

Sir, "Pravda" articles on the maiden flight of Buran have thrown doubt on Western reports about the existence of a Soviet Hermes class spaceplane to be launched by the SL-16 booster. These reports were largely based on the four SL-8 launched Cosmos scale model orbital flights from Kapustin Yar between 1982 and 1984 and a number of obscure suborbital tests over Soviet territory in the past four years, all of which were generally presumed to have been tests of scaled down versions of the 20 ton spaceplane.

Pravda now links the above projects to the research and development programme for the Buran class Space Shuttle Orbiter and says that they were designed to flight-rate the Shuttle's reusable heatshield. "A lot of attention was paid to tests of the heatshield", chief designers Valentin Glushko and Yuriy Semyonov point out in one article [1].

In another article leading Shuttle designers describe the Cosmos scale models as "the first ever Soviet aerospace flying apparatuses", adding that they allowed engineers to "study the working of the heat-resistant tiles and carbon nosecap in conditions close to those experienced by Buran" [2].

Even more significantly, two leading cosmonaut-designers have emphatically denied the existence of the Soviet spaceplane, Konstantin Feoktistov during a visit to Paris in October 1987 and Oleg Makarov in an interview for the French newspaper "Liberation" on November 15, 1988.

This still leaves the possibility that the Soviet spaceplane programme is a highly classified military project, which cosmonauts are simply not allowed to talk about. However, an earlier suggestion of a launch from the military space centre of Plesetsk (see ***Spaceflight***, May 1988, p.193) is groundless, since Plesetsk does not have the capability of launching the SL-16.

Furthermore, one might ask whether a Hermes class mini-Shuttle could actually play a valuable role in the Soviet space programme and if the Russians could financially afford to simultaneously run three independent manned space projects (Soyuz/Mir, Buran and the mini-Shuttle).

All this does not mean that the Soviet Union never studied alternative Shuttle designs (including the Hermes/Dyna Soar type configuration) before the Buran concept was adopted some ten years ago. One of Buran's designers, Vladimir Struminskiy, was quoted by Radio Moscow as saying that Soviet engineers began working on Shuttle type spacecraft as long ago as the late 1950s. "A spacecraft of that kind was built in the mid-1960s", he said, "although it was much smaller than Buran. It even went through tests, but the project was killed because it was considered too expensive" [3].

Another Radio Moscow programme said that back in the early 1960s Gagarin and other pioneer cosmonauts had done research into designing "an aerospacecraft that greatly resembled American Space Shuttles". "There was no continuation of that research", the report said. "One explanation is the level of space technology at that time would have made it impossible to do such work and would have needed a lot of funds as well" [4]. All this suggests that, as in the United States, the concept of flying people into space aboard winged spacecraft was very seriously studied by the Soviets in the early days of the Space Age, but eventually was dropped in favour of the simpler and less costly idea of launching manned ballistic capsules atop converted military missiles.

BART HENDRICKX
Kapellen, Belgium

References

1. Pravda, November 17, 1988, p.3.
2. Pravda, November 24, 1988, p 3.
3. Radio Moscow World Service, "Update", November 21, 1988.
4. Radio Moscow World Service, "Science and Engineering", November 19, 1988.

More Glasnost Needed

Sir, Now that a Soviet publication has officially acknowledged the occurrence of the "Nedelin catastrophe" of October 24, 1960, the time is ripe to summarise just how far "space glasnost" has gone and how much farther it has to go.

The 15-22 April 1989 issue of 'Ogonyok', No. 16, carried the article "Area-10" by Aleksandr Bolotin which refers to the designation of the barracks area of the base. The article fully and movingly describes the explosion at "Tyura-Tam" (the official Soviet spelling) at about 18:45 hours on the evening of October 24, 1960. The explosion killed Nedelin and a "substantial number" of other specialists, many of them identified (two, Nosov and Ostashev, have streets in Leninsk named after them). The booster was an R-16 ICBM ("SS-7" to NATO) from the Yangel Bureau in Dnepropetrovsk, at a pad about 20 km from the Sputnik launch site. Prior to liftoff, on-pad repairs had to be made to the fully-fuelled vehicle, and the replacement of a command unit caused an unexpected fire signal to be sent to the rocket's second stage, igniting its engine and immediately detonating the first stage. At the pad itself, only coins and pocket change were recovered from the victims. Yangel and a general named Mrykin went into the "smoking hut" for cigarettes, and survived. Much later, in a park in Leninsk, an obelisk was erected with the laconic inscription: "Eternal memory to those fallen in carrying out their military duty on October 24, 1960".

But questions remain: how many died then, how many died in other similar accidents, and when was the booster ultimately successful?

Group Photograph

Sir, I enclose a group photograph which shows the second group of so-called Interkosmonauts who arrived for training at Star Town in March 1978. They are from left-to-right, Georgi Ivanov (Bulgaria), Dumitru Dediu (Romania), Bertalan Farkas (Hungary) Aleksandr Aleksandrov (Bulgaria), Arnaldo Tamayo Mendez (Cuba), Bela Magyari (Hungary), Dumitru Prunariu (Romania), Jose Armando Lopez Falcon (Cuba), Jugderdemidiin Gurragcha and Maydarjaviyn Ganzorig (Both Mongolia).

Two Vietnamese cosmonauts were selected in 1979 to join the group by which time Ivanov had flown the abortive Soyuz 33 mission. The other men in the group to fly were Farkas, Tamayo Mendez, Prunariu and Gurragcha, all of whom flew to Salyut 6 and Aleksandrov who flew in 1988 to the Mir complex.

NICHOLAS E. STEGGALL
West Yorkshire, UK

My earlier reconstructions of this disaster showed many correct details but one major error, which was to identify the vehicle as a Mars probe (official Soviet data of the October 10 and 14 launch failures is still awaited).

Curtis Peebles raised the point that the Kremlin pressure to develop a workable ICBM, as opposed to the militarily useless "SS-6" from the Korolev KB, led to the decisions which killed the best engineers of the "Yangel Bureau". Subsequent launch failures of the SS-7 in 1961 contrasted with a burgeoning American ICBM force, which had been created under the incorrect impression, fostered by Khrushchev, that Soviet ICBM's were rolling off the assembly lines "like sausages" and led to Khrushchev's desperate gamble, the emplacement of missiles (and almost all existing Soviet nuclear missile warheads) in Cuba in 1962. The Nedelin catastrophe may have been a direct cause of the conditions leading to such a gamble.

One may speculate on the motivation for the above Soviet release of the Nedelin story.

First in contemporary importance is the level of military space activities, reflected in "Cosmos" satellite launchings which are still labelled as being for "space exploration". This is the most glaring example of where a policy change is needed so that TASS honestly describes the majority of vehicles as being for "defense purposes". Recent release of data showing that more than half of the space budget is for military purposes goes some way to facing this truth.

The "phantom satellite" designated 1985-53, launched June 21, 1985 remains off the Soviet space record books. Someday responsibility for it must be acknowledged. Photographs of Zenit may soon be published since drawings have just been released. Details of the mysterious test launches of Cosmos-1786, 1820, 1871 and 1873 may take a little longer to be released.

For the past three years, Soviet annual summaries have been listing "date of cessation of work" for all vehicles, which coincides with recovery dates or with breakdown dates. This data is given only for satellites launched that same year; someday retroactive data for satellites launched in previous years which subsequently "cease work" may be supplied.

If recoveries and breakdowns can be announced a year later, they should be announced when they occur. It is not too much to hope that TASS bulletins will eventually provide both liftoff time (not just date) and liftoff location.

Detailed information on Proton-D ("SL-12") vehicle flight history has been provided as part of commercialisation efforts and exact dates and causes of launch failures since 1970 released, except for the odd omission of Cosmos-419, known to be a Mars probe injection failure. Overall statistics for other commercially-offered vehicles (Vostok, Soyuz, Molniya, Tsyklon, Cosmos and Zenit) have been published but detailed lists of failures and causes have not been released. Such records ought to include all vehicles and all the early years. The dramatic booster explosion films (of 'semyorka' and even 'Vostok' rockets) shown on Soviet television in recent years should be identified with dates and intended missions.

Now that extensive details have come to light on the "missing cosmonauts" and other previously-unknown backup cosmonauts, on the Gagerin landing lie ("In his ship") and on his fatal accident, on the taboo name of "Tyura-Tam" and on the Nedelin catastrophe, further revelations maybe only a matter of time

CORRESPONDENCE

Who were the "six to eight" cosmonauts killed in training, as admitted by Shatalov to Stafford in 1973? We still only have the name of Bondarenko. The Soviets would be wise to release photographs of the shrine to martyred spacemen located in the administration building at Starry Town, just down the stairs from Shatalov's office and list all the names memorialized there.

Still unavailable are maps of Starry Town, of "Baikonur" (the geographical deception should be dropped and the name "Korolevsk" used instead) and of Plesetsk: access to the museum at the Korolev construction bureau in Kaliningrad is still restricted.

Soyuz-1 remains a major unresolved historical question. Contemporary official accounts still insist the cosmonaut completed all test objectives before dying in a freak end-of-mission glitch. Yet the two-ship linkup was the plan, and problems cropped up almost immediately after launch. Program officials had objected to the premature launch but had not been overruled.

The Soviets' man-to-the-Moon program of the 1960s is also still unveiled. Neither crew training in Zond capsules and the more advanced man-related lunar vehicles tested as Cosmos-379, 382, etc. have been disclosed.

Two separate sources have suggested that the super-booster "SL-15" or "TT-5" etc., was known to the Soviets as the "Enerdin' ("Ener-Dyne"). "It did not burn kerosene", noted one source; "it burned money". Another source repeated the old account of mass fatalities associated with the July 1969 pad failure. A recent memoir confirmed that the Energia/Buran launch pad was built as a modification to an "existing structure", but full details were not given.

The civilian Salyut failures of 1972 (at launch) and 1973 (in orbit, called Cosmos-557), the docking failures of Soyuz-3 (1968) and Soyuz-10 (1971) have still to be acknowledged and explained. Rendezvous failures of Soyuz-8 (1969), Soyuz-15 (1974), and Soyuz-23 (1976) also need to be explained in as much detail as has been the Soyuz-33 failure (1979) and the T-8 failure (1983).

Complete technical drawings and photographs of the Salyut-2, 3 and 5 vehicles (including landing capsules) have never been provided or details of the sudden termination of the Soyuz-21 mission in 1976. Configuration information on Cosmos-929, 1267, 1443 and 1686 is also lacking.

The mystery "twins" of the late 1970s are still to be explained: Cosmos 881/882 (December 15, 1976), a failure in August 1977, Cosmos 997/998 (March 30, 1978), and Cosmos 1100/1101 (May 22, 1979). These were recovered after one orbit and probably related to early space shuttle testing.

A recent Soviet newspaper denunciation of Western misinterpretations of the "spaceplanes" attacked reasonable speculation caused by Soviet silence on that program. Acknowledgement that four orbital tests were part of pre-Buran technology development is not enough. Suborbital tests have not been described nor photographs of pre-launch, liftoff, recovery, and post flight analysis released. Indeed no account has been provided of the fatality during the first Indian Ocean recovery.

Cosmos-1870 spacecraft ("Resurs-R") has not been explained, nor drawings, photographs, and samples of its radar and visual data published.

JAMES E. OBERG
Dickinson, Texas, USA

Neptune Encounter Debris?

Sir, With Voyager 2 soon to rendezvous with Neptune and the prospect of a partial ring system being found, I have re-read A.T. Lawton's article "The many shades of the 10th planet" (***Spaceflight***, March 1979, p.115-123) in which he discusses a possible interaction between the hypothetical 10th planet and Neptune, giving rise to the Pluto-Charon system and the retrograde nature of Triton's orbit. Since Lawton's article predates the suggestion of a Neptunian partial ring system, its discovery in August may add weight to his views and those of Lyttleton and Kuiper and Harrington and van Flandern, which he mentions.

Was the 10th planet so damaged as a result of this interaction that it may not, in fact, be extant as such but rather as an aggregation of orbiting debris, massive enough to cause the unexplained perturbations of Neptune and Uranus but invisible to observation due to its very fragmentation?

Secondly, the Pluto-Charon system may not just be a binary planet or a binary planetoid system but a "dirty system", being an orbiting composite of Pluto, Charon and other debris (although not a ring system) from the aforementioned interaction.

If partial rings and other orbiting material of potential encounter origin are found, either or both suggestions will, of course, not be proven but if no such material is found, then these views may well fall. I will, if necessary, be a cheerful casualty.

Dr. STEPHEN LEWIS
Cardiff, Wales

Brown Dwarf Companion to a White Dwarf Star

Sir, An infrared object has been found at 120 AU from the white dwarf GD 165, located in the constellation Bootes a few degrees south of the red giant star Arcturus. Images taken by Becklin and Zuckermann at several infrared wavelengths have led them to conclude that the companion, GD 165 B, hâs a surface temperature of 2100 K and a mass of 0.06 to 0.08 solar masses i.e. roughly 70 times the mass of Jupiter.

This is probably too small to be a true star, which shines through internal nuclear reactions, but it is glowing red hot through gravitational shrinkage processes similar to those occurring on Jupiter, but on a larger scale.

Becklin and Zuckermann have surveyed 200 white dwarfs and list a total of 9 (including GD 165) believed to have or have been proved to be accompanied by brown dwarf companions. They state that this survey has shown that brown dwarfs, either as companions to other stars or by themselves, could form the majority of the dark matter believed to exist between stars.

This is the first *positive* indication that smaller bodies than stars do exist elsewhere.

Developments of these techniques might be able to image smaller and cooler objects (5-10 x Jupiter mass) that are orbiting white dwarfs.

A.T. LAWTON
W.Sussex, UK

Ariane Launchers

Sir, I notice in the April edition of ***Spaceflight*** an article concerning the ordering of 50 Ariane 4 launchers. In this article, you specifically mention the roles of British Aerospace and Ferranti.

Could I bring to your attention the role of EASAMS in this programme? As contractors for the Flight Program we are intimately involved in each launch, providing a critical component for flight. Ariane 4 can fly without SPELDA (when only one satellite is being carried) and without the Ferranti platform: it cannot fly without an EASAMS Flight Program.

R.J. SMITH
Project Manager, Software Division
EASAMS, Surrey, UK

New Shuttle Boosters in 1994

NASA has selected a joint Lockheed-Aerojet team to build the next generation of Solid Rocket Boosters (SRBs) for the Space Shuttle. The Advanced Solid Rocket Motor (ASRM) will increase the Shuttle's payload capacity and improve safety. In 1994 the ASRM will replace the present SRBs, manufactured by Morton Thiokol, which were redesigned following the Challenger accident.

The ARMS will increase the Shuttle's payload capacity by 12,000 pounds, allowing NASA to achieve its originally goal of 65,000 pounds per orbit. Based on 14 flights annually, the extra payload capacity is the equivalent of an additional 2.4 flights per year. With this in mind, the development costs should be recovered in four years.

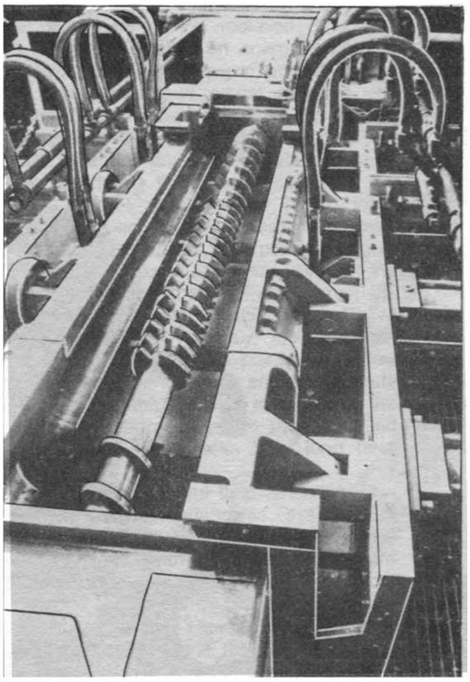
The overall cost of design and development, including the cost of motors for six Shuttle flights, is estimated at just under $1 billion, excluding the costs of facilities which are estimated at $200 to $300 million.

The ASRM manufacturing plant will be built at Yellow Creak, Mississippi on the Tennessee River, construction work is expected to begin this summer. Other facilities will include test installations at NASA's Marshall Space Flight Center and a static test stand at the Stennis Space Center.

In 1993 Aerojet will start manufacture of the ASRMs, leading to a production rate of 32 motors per year. Starting in 1994, ASRM will be barged down inland waterways enroute to the Kennedy Space Center for Shuttle launches.

The ASRM propellant will be manufactured by Aerojet's continuous mix process. This maximizes propellant consistency and allows for continuous assessment of the propellant rather than random sampling.

Each 126 foot long motor will have three segments, one less than the present Thiokol motor. The field joints will be of a better design than the present boosters. The ASRM is able to deliver more thrust because the motor's diameter has been increased from the current 146 inches to 150 inches, adding 200,000 pounds of propellant per motor. The ASRM will adjust thrust, throttling down as the Shuttle passes through maximum aerodynamic stress, eliminating safety problems caused by varying the power levels on the Shuttle's main engines.



This pilot plant shows the type of automated continuous mix machinery that Aerojet will operate at Yellow Creek, Mississippi, to manufacture the ASRM. The casing is open to show the horizontal interrupted screw that will combine oxidizers, pre-mixed fuels and curing agents into the most advanced solid propellant. *Lockheed*

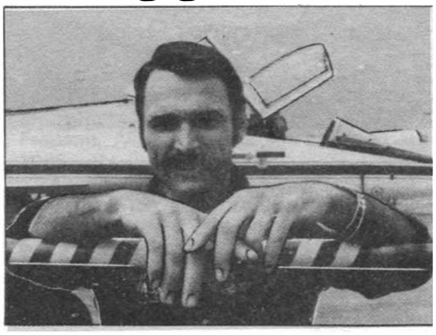
Shuttle Pilot Griggs Dies

We are sad to record the death of astronaut S. David Griggs on June 17. Griggs died when his single-engined 1944 North American Harvard AT-6D trainer crashed. He had flown aboard the Space Shuttle Discovery in 1985 and was due to pilot the STS-33 mission scheduled for later this year.

Griggs was buried at Arlington National Cemetery on June 21, with members of the astronaut corp and other NASA employees in attendance. Astronaut Office Chief Daniel Brandenstein delivered a eulogy as part of the 25 minute service and 51-D crew mates Karol Bobko and Jeff Hoffman served as family escorts. Also present were NASA Administrator Richard Truly and Johnson Space Center Deputy Director Paul Weitz, both former astronauts.

Brandenstein described Griggs as "a very motivated, hard working individual." He went on to say. "He has made numerous contributions to the programme throughout his stay here. He was practically solely responsible for the Head-Up Display, he did extensive work on orbital manoeuvring vehicles and crew rescue and space station development. He was just a hard-charging, get-the-job-done kind of individual. His dedication and talents will be sorely missed in the office."

Griggs was born on September 7, 1939 in Portland, Oregon. He joined NASA in 1970, working as a research pilot at the Lyndon B. Johnson Space Center. In 1974 he was assigned duties as the project pilot for the Shuttle Training Aircraft and participated in the design, development and testing of those aircraft pending their operational deployment in 1976. He was appointed Chief of the Shuttle Training Aircraft Operations Office in January 1976.



Astronaut S. David Griggs leans on the nose lightning rod of a T-38 trainer. *NASA*

In January 1978 Griggs was selected as an astronaut candidate and in August 1979 he successfully completed his training.

From 1979 to 1983 Griggs was involved in many aspects of the Shuttle programme including the development and testing of the Head-Up Display, the development of the Manned Manoeuvring Unit and the definition and verification of on-orbit rendezvous and entry flight phase software and procedures.

In September 1983 Griggs began training as a mission specialist for Shuttle mission STS 51-D, which flew April 12-19, 1985. During the flight Griggs and fellow astronaut Jeff Hoffman conducted the first unscheduled space walk in the history of the US space programme. The space walk lasted for over three hours during which the astronauts attached a 'fly swat' to the end of the remote manipulator arm as part of an operation to revive a disabled satellite.

Griggs was training as the pilot for STS-33, a Shuttle mission for the Department of Defense currently scheduled for launch on November 19. Griggs has been replaced by John Blaha who has been transferred from mission STS-40, due for launch in August 1990. Blaha made his first space flight on STS-29 in March of this year. Blaha is to be replaced on STS-40 by Sydney Gutierrez.

Griggs leaves a wife, Karen, and two daughters, Alison and Carre, to whom we extend our sincere condolences.

Aircraft to Test Shuttle Landing Gear

A NASA Convair-900 aircraft will be used next year for extensive tests of Space Shuttle landing gear assemblies, from normal conditions up to and including failures. The tests are to be conducted at NASA's Ames-Dryden Flight Research Facility in California.

Data from the landing tests will give engineers information on what to expect should an orbiter experience a flat tyre or other problems on landing and will provide data to help in developing new crew procedures for various landing conditions.

The test gear assembly will be mounted on the aircraft's fuselage between the main tyres and a hole will be cut in the fuselage to accommodate raising and lowering the gear.

High speed video and film cameras, in addition to other instrumentation, will record the test for thorough analysis.

The official STS-28 crew portrait: (Left to Right) Richard Richards, Mark Brown, Brewster Shaw, Janes Adamson and David Leestma. *NASA*

Columbia Readied For Return to Flight

The Space Shuttle Columbia has waited three and a half years to make its eighth space flight. Columbia last flew in to orbit in January 1986 on mission STS 61-C. It was scheduled to fly again on March 6, 1986, but the Challenger accident left Columbia firmly grounded. Columbia will return to flight in early August when it blasts off on a mission for the US Department of Defense (DoD).

Commander for STS-28 will be Brewster Shaw, a veteran of two Shuttle flights (STS-9 in November 1983 and STS 61-B in November 1985). Richard Richards, pilot, will be making his first space flight. Mission Specialists for STS-28 are: David Leestma (who flew on STS 41-G in October 1984), James Adamson (making his first space flight) and Mark Brown (also making his first space flight).

Launch Preparations

STS-28 has suffered a number of delays During the halt in Shuttle operations NASA took the opportunity to refit Columbia including major work on the orbiter's heat resistant tiles. Unfortunately, work on Columbia fell behind when earlier Shuttle

STS-28
Preview

missions took priority. STS-28 was originally scheduled for launch on July 1. When it became apparent Columbia would not be ready in time NASA rescheduled the launch for July 31 at the earliest. However by mid-July there was no contingency time left in the schedule and the launch will almost certainly to be delayed until early August.

While Discovery and Atlantis were prepared for their missions, Columbia was housed in the Orbiter Maintenance and Refurbishment Facility. The orbiter was transferred to the Orbiter Processing Facility (OPF) on January 23, where work to prepare her for STS-28 could begin in earnest.

Modifications, introduced after the Challenger accident, have been made to Columbia, including the installation of the crew escape pole. When Columbia began its processing flow 2,300 tiles were missing from the orbiter's skin. Work to fit the tiles continued along side other preparations.

In early May the three main engines were installed. Dunng checks of the engines the No.1 engine was found to have a leaking high pressure hydrogen turbopump. Replacement of the pump did not go as planned. Difficulties with ground support equipment delayed the removal of the old pump and the insertion of the replacement. Then technicians had to remove and reinstall the new pump three times because of leaks between the main combustion chamber the turbopump. Yet another leak was discovered in a bearing cap on the pump. In this case technicians were able the correct the problem in less than a day. The operation to replace the pump took two weeks.

The STS-28 crew looked over their space craft in early June to check for any sharp edges or items that could be installed differently. The crew had visited the space center a week earlier to review the launch preparations.

With just minor tile work remaining Columbia was rolled over to the Vehicle Assembly Building (VAB) on July 3. Work to mate the orbiter to the External Tank and

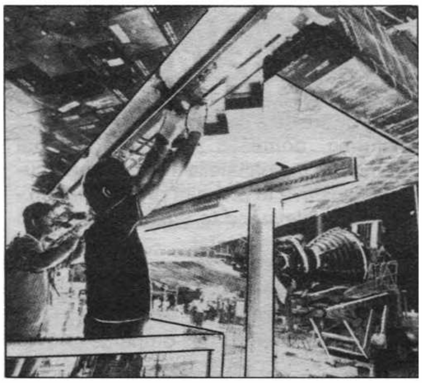
SRBs continued from July 5-6. The Shuttle Interface Test (SIT) began on July 10. The SIT involves testing all the electrical and mechanical connections between the SRBs, External Tank, Orbiter and Mobile Launch Platform. The test had to be halted on July 11 when an electrical problem was detected in the right hand SRB. The test resumed and was expected to continue until just prior to the roll out to the launch pad, scheduled for the early hours of July 14. While the SIT continued last minute tile work on the left wing was completed.

The STS-28 crew were due to arrive at the Kennedy Space Center on July 16 for the Countdown Demonstration Test which will conclude on July 18 with a simulated blast-off at 11:00am EDT.

A Flight Readiness Review is planned for July 25-26 and a firm launch date will be announced then.

The Mission

Columbia is expected to enter a 57 degree inclination, 160 nautical mile circular orbit. During the flight, which will last three to four days, two military satellites will deployed from the orbiter's payload bay. In addition to the satellites a number of secondary payloads will be carried. They include: a contamination monitor, a stellar reference system, one or more Get Away Special canisters, a low altitude heavy ion experiment, a radiation monitoring experiment and longitude and latitude monitoring equipment.



Kennedy Space Center tile technicians continue their work on the Space Shuttle Columbia as one of the three main engines is prepared for installation. *NASA*

After completing its mission Columbia will land at Edwards Air Force Base in Califorinia.

Radiation Monitoring

Aboard Columbia on STS-28 will be a highly advanced device for gauging the amount of radiation astronauts and equipment receive in space.

"Space has different kinds and intensities of natural radiation not found on Earth. As the potential for long term space exploration draws closer, we must determine the biological health effects of radiation and its impact on spacecraft and equipment," said Leslie A. Braby, a staff scientist at Battelle, the developers of the radiation detector.

The device, called an energy deposition spectrometer, will categorize and record the charactenstics of orbital radiation and its impact on human cells into 16 different deposition ranges. The data collected will result in a bar graph of minute-by-minute exposure during the Shuttle's orbits of the Earth. Current spectrometers record information into only three deposition ranges.

"The spectrometer will provide important data on a particular orbital zone off the Argentina coast that delivers unusually high doses of radiation," said Braby Called the South Atlantic Anomaly, the zone can provide more radiation exposure in a few minutes than the Shuttle's entire 90 minute orbit of the Earth. "We want to determine the types of radiation present in this zone and the potential health risks from long term exposure."

The device will also help determine how radiation affects electronic systems in spacecraft. "Radiation particles in space can interfere with computers onboard Shuttles or satellites, causing electrical circuits to malfunction," Braby said. "Once we determine the environmental circumstances that produce the malfunctions, preventive measures can be taken and new computers developed that are immune to radiation interferences."

New Shuttle Launch Schedule

Hubble Telescope Postponed until March 1990

NASA has recently released an updated Shuttle launch schedule. The new manifest shows four flights remaining in 1989, nine in 1990, eight in 1991, 12 in 1992 including four flights of the new orbiter Endeavour, 14 in 1993, 13 in 1994 and 10 in 1995 through September 1995.

The planetary schedule is maintained with the deployment of the Galileo probe to Jupiter from Atlantis on October 12 on mission STS-34. The Ulysses probe to the Sun remains scheduled for October 1990.

Launch of the first of the great observatories, the Hubble Space Telescope, has slipped from December to March 1990 in order to protect retrieval of the Long Duration Exposure Facility (LDEF) deployed on mission STS 41-C in April 1984.

Recognising the significance of recovering LDEF, the STS-32 mission is now planned for December 18 aboard Columbia. The free-flying satellite carrying 57 science, technology and applications experiments is in danger of reentering the Earth's atmosphere if not recovered by early 1990. In addition to retrieving LDEF, the Syncom IV-05 satellite will be deployed for the Navy.

In support of Earth sciences, six additional Shuttle Solar Backscatter Ultraviolet (SSBUV) missions have been added to the line-up and the four previously-manifested SSBUV missions have been accelerated. This instrumentation maintains an accurate measurement of global ozone.

Other major science mission changes include the Astro-1 mission in April 1990, the Gamma Ray Observatory flight now in June 1990 and the Spacelab Life Sciences flight in August 1990.

The new manifest includes the first three assembly missions for the Space Station Freedom. All three flights are baselined in 1995.

Also planned are two Flight Telerobotic Servicer (FTS) demonstration test flights. FTS is a system being developed for the space station to assist in assembly, service and inspection of the manned base and its attached payloads.

In the international area, a third European Retrievable Carrier (EURECA-3L) deployment is now slated for launch in May 1995. Eureca is a platform to be placed in orbit for six months, offering conventional services to experimenters.

Two additional Spacehab module flights have been booked, bringing the total number of planned flights to six. Spacehab is a commercially-owned, pressurised module for conducting experiments in a Shuttle middeck environment.

The updated manifest also features six Shuttle "flight opportunities" beginning in 1992. Use of these flight opportunities by payloads which slip from their planned launch will minimise manifest revisions and promote schedule stability in payload programmes.

Engine Fire Should Not Delay Columbia

A Space Shuttle Main Engine (SSME) undergoing a test firing automatically shut down and caught fire near the completion of the long duration test. Shuttle managers believe the incident will not affect STS-28.

A SSME development engine shut down automatically 21 minutes into a planned 22.25 minute firing designed to test several modified engine components. As it shut down, fire broke out around the engine's powerhead. The test was taking place at NASA's Stennis Space Center in Bay, St. Louis, Mississippi.

An early inspection of the engine showed significant damage to the engine's high pressure oxidiser turbopump. The engine has been flown to its manufacturer, Rocketdyne for a detailed examination.

Shuttle managers, at the Kennedy Space Center for a roll out review meeting, decided to proceed as planned with the schedule until a 12-member board of investigation determines the cause of the damage during the extended duration test.

Mission Specialists Assigned

Astronauts Mary Cleave and Norman Thagard, who recently flew on Shuttle mission STS-30, have been named as Mission Specialists for STS-42, a nine day flight aboard Columbia, set for December 1990. The partial crew assignment will allow long-range payload training and integration associated with the International Microgravity Laboratory (IML-1), says NASA.

Anniversary Stamps

It has been a pleasure for me to consider putting together a collection of stamps commemorating the 20th Anniversary of the First Manned Landing on the Moon. I am not so sure that this will culminate in a complete collection because I do not know just how many sets on this theme will be released by the 240-odd stamp issuing authorities on plant Earth.

To simplify my selection, I think I might start with the CAPHCO Omnibus of twelve original sets each comprising stamps and souvenir sheet. But a few words first about CAPHCO.

CAPHCO only became a limited company in 1985 after over 120 years of practical experience with postage stamps. It took over the Crown Agents Stamp Bureau, which commenced operations in 1848 when a contract to print the "Britannia" series for Mauritius was placed with Perkins Bacon, the printers of the Penny Black. By the 1860s the Crown Agents were arranging for the design and printing of many colonial stamps.

Today, CAPHCO is renowned for its prudent policy-advice to nearly 50 stamp - issuing nations. It is very important to carefully create a balance between stamps featuring domestic and international themes as the philatelic market is particularly sensitive to any hint of exploitation - thematic relevance to the issuing nation is desirable, if not vital.

CAPHCO and NASA

CAPHCO contacted the NASA at the conceptual stage of this omnibus and received 100% co-operation from the outset. All the illustrations on the stamps are authentic. Highlights include the inside of NASA's Firing Room, rockets at lift- off, modules in orbit, astronauts and vehicles on the Moon, parachuting spashdowns and recovery operations.

Project Mercury was launched in 1961 with suborbital flights by Alan Shephard and Virgil Grissom. It was only 20 days later that President Kennedy went before Congress and called for a national effort to send men to the Moon and back before the end of the decade.

The Apollo 11 Mission

July 16 was the day chosen for the launch of Apollo 11. On the launch pad, the majestic rocket rose 363 ft into the air. More than nine million parts were hidden beneath its sleek exterior. At 9.32 am the five mighty engines of the Saturn V lifted the rocket from the ground atop a pillar of flame in a never-to-be-forgotten spectacle.

Down to Earth

On July 21, after performing a number of experiments. Armstrong and Aldrin departed on the first leg of what was to be a triumphant return to Earth. A small stainless steel plaque on a leg of the module, remaining behind stated:

'Here men from the Planet Earth first set foot upon the Moon. July 1969 AD. We came in peace for all mankind.

The following countries are participating in the CAPHCO omnibus:

Ascension Island * Bahamas * Belize * Kiribati * Liberia * Nevis* St. Kitts * Samoa * Seychelles * Solomon Islands * Venuatu * Zil Elwannyen Sesel

I am particularly fascinated by the Ascension Island 15p value.

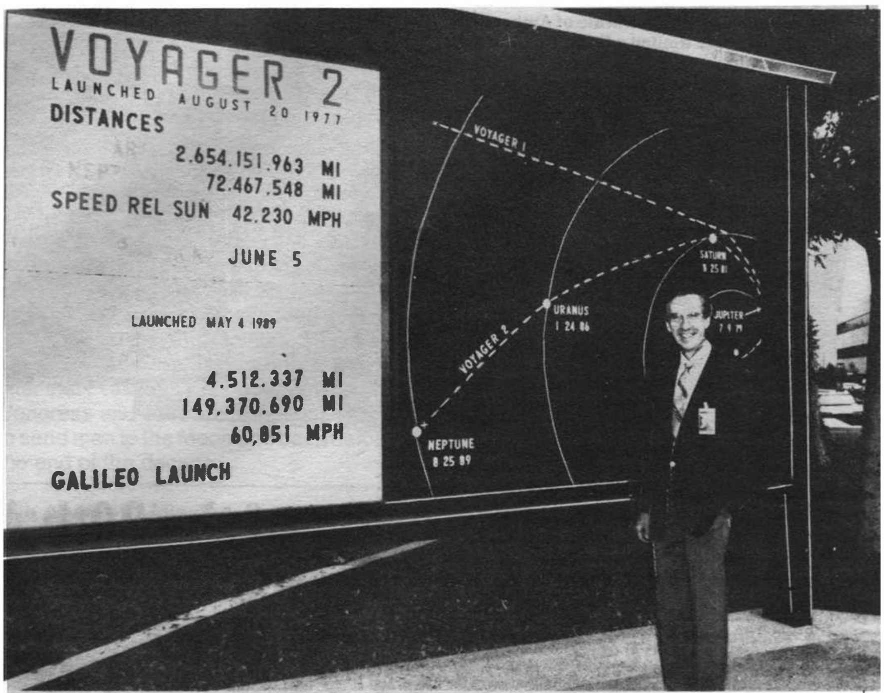
SPACE AT JPL

The latest news from Dr. William McLaughlin at the Jet Propulsion Laboratory in California.

Planetary Summer

There is a large display board that stands in the Mall at JPL and posted on it is the current status of missions in flight. For over a decade only Voyager data has been present. But now, Voyager 2's progress toward Neptune is supplemented by information on Magellan's cruise to Venus, and the countdown to the October launch of Galileo, on its Jovian mission is tallied. Three missions, three planets, and the California summer glows even brighter with the promise of planetary adventure.

The opening of Magellan's launch window for Venus was on Friday, April 28 and television monitors throughout JPL carried the countdown. When the launch was scrubbed, due to problems with the Shuttle Atlantis, the waiting began to find out when a second attempt would be made. On Thursday, May 4, the faithful reconvened in front of television monitors at the Laboratory and once more sweated out the countdown. The adequacy of the weather to accompany certain launch-abort scenarios was marginal, but conditions were finally judged suitable and Magellan soared upward at 2:46:59 pm. Eastern Daylight Time.



James S. Carter, Chief of Magellan's Mission and Sequence Design Team, stands by the mission status board at JPL. Voyager trajectories, Magellan statistics and the countdown to the launch of Galileo are displayed. *NASA/JPL*

In the April issue, I presented the results of a (prelaunch) discussion with James S. Carter, Chief of Magellan's Mission and Sequence Design Team (MSDT). The MSDT constructs a detailed layout of each two-week period of activities during the cruise to Venus and feeds this profile to the Spacecraft Team, which then generates the appropriate commands to be sent to Magellan. (Upon arrival at Venus in August 1990, the MSDT will similarly support the radar-mapping mission as the spacecraft orbits the planet every 3.15 hours.) In June, I returned to talk with Carter in order to compare postlaunch reality with prelaunch expectations.

The first piece of information for the MSDT was, of course, the fact that launch and the subsequent injection into interplanetary cruise were successful; the MSDT and other elements of the flight team were in business. Injection was accomplished, after deployment from the Shuttle, by an Inertial Upper Stage (IUS) rocket. The time of separation (10:27:10 pm, Eastern Daylight time on May 4) of the spacecraft from the solid-stage IUS was the second piece of information required for the MSDT to go to work.

The Galileo spacecraft and support equipment begin their 4 1/2 day ride from JPL to the Kennedy Space Center. *NASA/JPL*

The team's first task was to update a set of real-time commands, collectively called "Cruise O", which were sent to Magellan on Saturday, May 6, in order to bring its onboard computers to states consistent with this period of the mission. Two days later, on Monday, the "Cruise 1" sequence of commands was sent to the spacecraft. Cruise 1, and subsequent loads, each spanning two weeks, are stored onboard the spacecraft as a set of time-tagged commands, each of which is executed when the spacecraft clock agrees with the command's time tag. This is the normal mode of controlling Magellan, Voyager, and Galileo. Real-time commands, exemplified by Cruise O, are executed upon receipt and are used as supplements to cover special situations

Carter said that launch operations and early cruise have proved, so far, to be reasonably smooth. Intensive training before launch paid off for the flight team, and no major hardware anomalies have occurred. Most of us carried in mind the trying experiences after the launch of Voyager 2 in 1977 and were relieved that history declined to repeat itself.

A significant milestone was passed on May 21 (or May 22, at 02:00, in the Universal Time System) with the successful execution of the first trajectory-correction manoeuvre, a small propulsive event which changed the velocity of the spacecraft by 2.9 m/s, utilising 4.2 kg of hydrazine propellant.

At present, the MSDT is occupied full

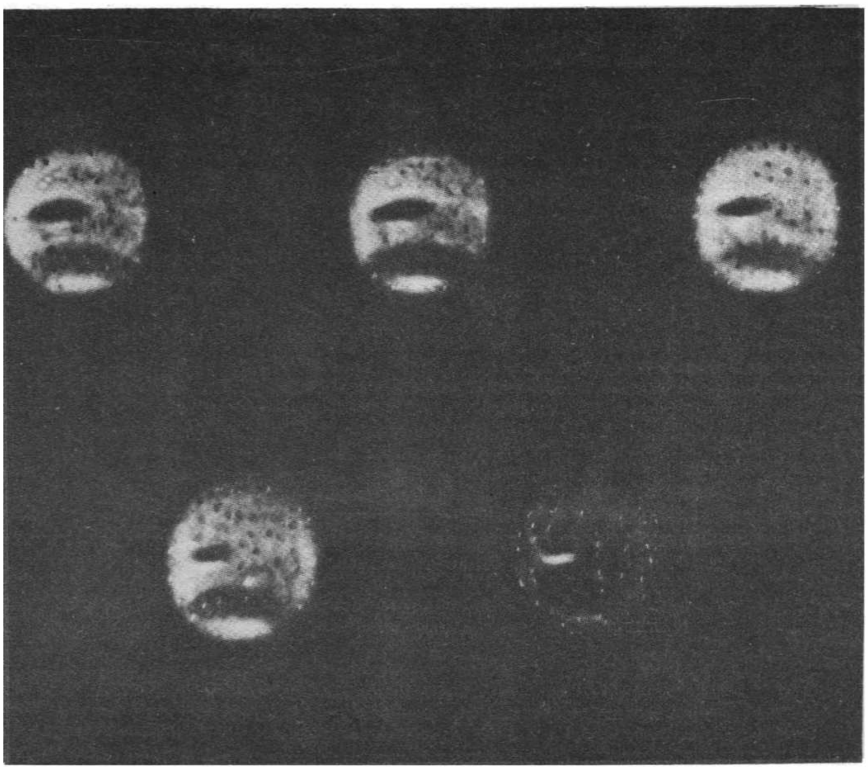
time in keeping up with their duties with regard to the generation of cruise loads for the spacecraft. Carter's intention is to automate selected activities - replacing human effort with the labour of computers - in order to create some time for the MSDT to engage in planning their work after insertion into orbit about Venus in little more than a year from now. "Incremental automation", the process of automating activities bit-by-bit in the light of experience, is a grassroots activity that has paid considerable dividends for Voyager over the years, and it is encouraging to see the emergence of this efficiency measure so early on Magellan. For example, the MSDT needs to examine in more detail their plans for that period of time, a few months after insertion into orbit about Venus, when Magellan will be carried behind the Sun with the sweep of Venus along its solar orbit. The radar survey of the planet will be interrupted for several weeks due to the inability to downlink high-rate data, but care and tending of the spacecraft is necessary so that it emerges in healthy condition from telecommunications exile (even low-rate transmission of commands to the spacecraft will not be possible for several days as a result of solar interference).

While Magellan has just set sail for Venus (what would an historian have made of such a phrase 50 years ago?), Voyager 2 is nearing the end of its 3 1/2 year cruise from Uranus to Neptune. Like Magellan, Voyager 2 consumed command loads during its cruise period: testing newly developed spacecraft capabilities for the Neptune encounter and obtaining scientific data about interplanetary space (plus observations in the ultraviolet of selected astronomical objects). A parallel activity took place during cruise with the crafting of the ten computer command loads for the spacecraft that would carry out the observing program during the encounter period, from June 5 through October 2.

With preliminary versions of these loads "on the shelf", the process of updating them began in late February of this year and will continue until early September. Each update requires between 9 and 16 weeks, and at one time, in late June, the schedule had eight of the ten loads simultaneously being updated: a busy summer!

Among the numerous other activities being handled by the flight team is agreement upon an accurate set of important physical constants. The great distance of Neptune from the Sun makes it very difficult to obtain an accurate set of constants, yet such knowledge is essential for planning and executing the close flyby of Neptune and its large satellite Triton (see the December 1988 edition of this column for a summary of the major events of the near-encounter period).

Quantities such as Neptune's ephemeris, mass, size, shape, orientation, rotation rate, etc. are clearly important to planners and navigators, but the list is considerably longer and also takes into account the ephemerides and physical characteristics of the two known satellites - small Nereid in addition to Triton - plus best estimates for the possible system of ring arcs, and much more. The set of constants is kept up to date as new information is obtained during the approach to Neptune and, after the encounter, will constitute an important component of our new-found understanding of the planetary system.



These five images of Neptune were taken by Voyager 2 on May 24, 1989 at a range of 134 million km from the planet. The images were taken with various filters. The top row of three images employed violet, blue and unfiltered light (left to right) while the two images on the bottom row were green (left) and orange (right) filters. *NASA/JPL*

One of the most crucial updates to the constants will take place in the few days before the August 25 closest approach to the planet (at 04:00 UTC) when the ephemerides of Neptune and Triton are finally determined with high accuracy by the Navigation Team using, primarily, images from the onboard camera system. This information, in concert with an accurate ephemeris for the spacecraft (computed from a combination of optical data and radio tracking data), will be employed to tune at "the last minute" the command load spanning the closest approach period. This action is necessary to insure accurate pointing of the spacecraft's remote-sensing instruments and execution of its intricate radio-science experiments.

Galileo is the third ingredient in the planetary summer - if one stretches with authorial license the seasonal label to include not only the May launch of Magellan but also the scheduled October 12 launch date of Galileo. When the Challenger exploded in January 1986, the spacecraft was within a few months of launch and had to be returned from the Kennedy Space Center (KSC) to JPL for modifications to accommodate its new mission plan; see the May 1987 "Space at JPL" for a summary of the hardware changes. For the 1986 launch, Galileo would have arrived at Jupiter in 1988 after a direct flight from Earth. Now, with the abolition of the powerful Centaur rocket as an upper stage for the Shuttle, a more circuitous route, through the inner solar system, had to be devised in order to take advantage of gravity assists from Venus and Earth. The spacecraft will arrive at Jupiter on December 7, 1995.

The spacecraft arrived at KSC on May 16, 1989 after a 4 1/2 day cross-country trip A "pre-ship" event was held at JPL on Saturday, May 6 with a series of public displays and lectures. Project manager Richard Spehalski and other members of the Galileo team presented aspects of the mission and science objectives, and visitors had the opportunity to sign a register which was subsequently processed and placed onboard the spacecraft to accompany it in flight.

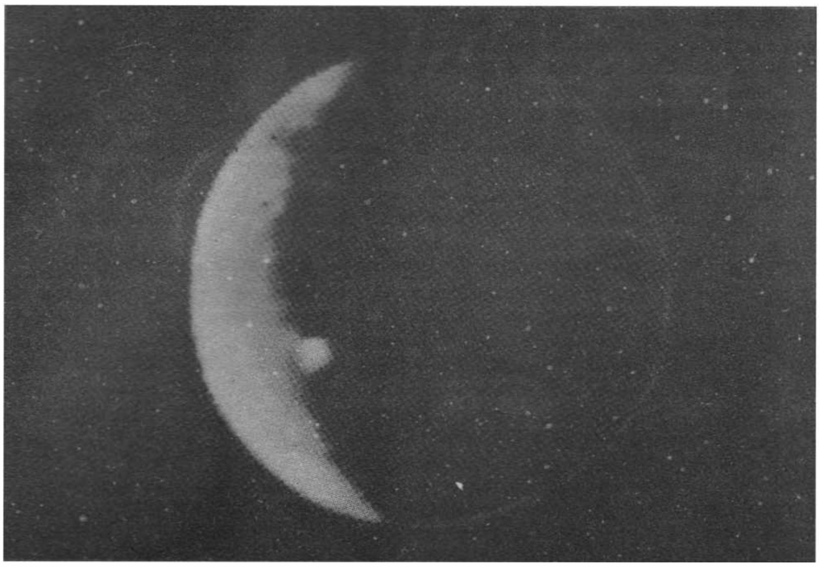
Upon arrival at KSC, the Galileo orbiter began a series of tests prior to mating with the (Jovian) atmospheric Probe. The next step will consist of a move to the Vertical Processing Facility for mating with the IUS booster rocket. In late August, the stack is scheduled for transport to launch pad 39-B and subsequent incorporation into the Shuttle Atlantis.

Do you remember science-fiction writer Ray Bradbury's "Rocket Summer"? It was the initial piece in his 1950 collection *The Martian Chronicles*, and when I was 15, this vignette, set in January 1999, seemed to me to be the apotheosis of optimism and adventure. "Rocket Summer... The Rocket lay on the launching field, blowing out pink clouds of fire and oven heat. The rocket stood in the cold winter morning, making summer with every breath of its mighty exhausts. The rocket made climates, and summer lay for a brief moment upon the land...".

Our planetary summer seems a worthy companion of this vision.

Volcanos on Io

Volcanos on Earth are ferocious geological beasts. Their predatory effects need not be restricted to the immediate vicinity of an eruption; climatic changes induced by material spewed into the stratosphere have caused crop failures, with attendant loss of life, at widely dispersed points. (See the May 1989 edition of this column for a report on some detective work concerning great volcanic explosions throughout history.) However, in the larger setting of solar system events, active vulcanism was unrecognised outside of Earth until the two Voyager spacecraft flew through the Jovian system in 1979 and observed volcanic eruptions in progress on the satellite Io.



Volcanos on the Jovian satellite Io were discovered with this image taken on March 8, 1979 by Voyager 1 at a range of 4.5 million km from the satellite. One plume is seen on the limb of Io, a second eruption is taking place along the terminator *NASA/JPL*

Io is the innermost of the four large satellites of Jupiter that were discovered by Galileo when he turned his telescope to the planet. Along with Europa, the next Galilean satellite in distance from Jupiter, Io is largely a rocky body (although Europa does have a thin coating of ice) and both are about the size of our Moon. The two outer Galilean satellites, Ganymede and Callisto, are larger with diameters more nearly equal to the planet Mercury, but with substantially lower densities than Io and Europa. The difference between these two pairs of satellites seems to be that the inner ones lost much of their less dense, volatile materials early in the history of the Jovian system. Jupiter, then very hot, "cooked" out most of the water and other volatiles from Io and Europa, leaving principally a rocky residuum. A second possible explanation is that the formation environment was sufficiently hot to prevent the initial incorporation of solid volatiles into the two inner satellites, and, in fact, both processes probably played a role.

Today, Jupiter still radiates twice as much energy as it receives from the Sun - energy from the original formation of the planet and the decay of radioactive elements - but the primary effect of the planet upon Io is now gravitational rather than thermal.

An intricate gravitational interaction between Jupiter, Europa, and Io produces tidal heating of Io - rock tides, not water tides - that drives the volcanos observed on the satellite during the flybys of Voyager 1 and 2.

The Voyager spacecraft provided striking images of the mottled orange-yellow topography of Io: painted with sulphur and its compounds by actively spewing volcanos, nine of which were catalogued by Voyager. Sulphur constitutes the motif for this Dante-esque world where even the orbit of the satellite is enveloped in a swirl of sulphurous material.

In late 1995, the Galileo spacecraft is scheduled to go into orbit about Jupiter, extending, among other objectives, our knowledge of Io's vulcanism. However, the progress of Io studies is by no means limited to data obtained from interplanetary spacecraft. Recently, I spoke with Dr. Dennis L. Matson of JPL in order to become acquainted with some of the Earth-based studies in which he is engaged. The substance of this conversation is reported below and illustrates the interplay.

Matson and his colleagues designed an observing programme that was originally focused upon understanding the heat flow from Io. Thus, it was natural to utilise measurements in the infrared portion of the electromagnetic spectrum, and, to this end, he employed NASA's three-meter Infrared Telescope Facility (IRTF) located atop Mauna Kea in Hawaii. The observational program, extending from 1983 to the present, included a period of time when a massive eruptive event took place on the satellite.

The observations suggest that on August 7, 1986 an area approximately 30 km in diameter produced temperatures of about 900°K.

Now this is very interesting: (1) the magnitude of the event, which had a power of approximately 2.6 x 10^{13} W, exceeded any release observed by Voyager, and (2) the 900°K observed temperature was significantly higher than the boiling point of sulphur: estimated to be about 715°K under the conditions at Io.

It had long been conjectured, by Dr. Michael Carr and others, that sulphur is not the only constituent in Io's vulcanism. The scarps and mountains which rise as high as 10 km above the mean surface of Io cannot be supported structurally by sulphur alone. A mixture of sulphur and silicates could do the job. Most investigators believe that both sulphur and silicate vulcanism is taking place on Io; the question at issue concerns the relative proportion of each and their attendant effects on the landforms of Io.

The IRTF was used to measure infrared flux from the satellite at three wavelengths: 4.8, 8.7 and 20 microns (a micron is one millionth of a metre and visible light extends from 0.4 to 0.7 microns). Each measurement summed the flux from the entire visible hemisphere of Io; the disk only subtends an angle of about one arcsecond as seen from Earth, and it is difficult to achieve optical resolution on this scale because of the jitter of the atmosphere.

However, surface resolution is obtainable through two methods: (1) observation of Io at different places in its orbit about Jupiter, thus viewing various hemispherical caps, and (2) using the fact that the three infrared wavelengths provide windows on different physical processes. The 20 micron measurements characterise emission from nonvolcanic cold areas of Io's surface, which constitute approximately 99% of the topography, while the 8.7 micron data supply information about cooler volcanic activity. The 4.8 micron flux encodes hotter volcanic activity and includes an infrared component from reflected sunlight. (Throughout the electromagnetic spectrum, shorter wavelengths correspond to higher energy processes, and, where temperature is relevant, hotter events.)

During the 1986 observing opportunity, observations were made with the IRTF on seven nights. On August 7, the 20 micron flux was normal, but the 8.7 and 4.8 micron fluxes were both increased significantly above normal levels: the former by a factor of two and the latter by a factor of four. From an analysis of the geometry of the observations, it was estimated that the location of the anomalous event was probably near 70° W. longitude. There is no way to estimate latitude, but the motion of Io in its orbit during the evening supplied enough information to constrain longitude. The observed fluxes would be reasonably explained by a volcanic source at the equator with the previously mentioned diameter of 30 km and

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По подписке 1989 г.

September 1989 US$3.00 £1.25

Spaceflight

The International Magazine of Space and Astronautics

President Bush Announcement

RETURN to the MOON

Lectures

4 October 1989 7.00-8.30pm

BEHIND THE SCENES WITH MAGELLAN, VOYAGER AND GALILEO

Interplanetary exploration is showing a strong resurgence in 1989 with three major events leading the way: The Magellan launch to Venus, Voyager 2's flyby of Neptune and the Galileo launch to Jupiter. Bill McLaughlin, who is involved with all three projects at the Jet Propulsion Laboratory, will outline the missions and provide insights into the actual progress and results to date of these three endeavours.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

1 November 1989 7.00-8.30pm

CETI OVERVIEW - AN UPDATE

A. T. Lawton

Recent observations have revealed that at least two nearby stars have "Brown Dwarf" mini-stars as companions. Such studies will undoubtedly lead to the discovery of Brown Dwarfs as individual single stars, so that Proxima Centauri may not be our nearest extra-solar body.
The impact of these new discoveries on the more conventional ideas of CETI will be discussed.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Technical Symposia

13 September 1989 10.00am-4.30pm

SPACE STATIONS AND BEYOND

The 2nd BIS Space Infrastructure Symposium

Following the success of the first infrastructure symposium in November 1988, the British Interplanetary Society is organising a second with the theme of "Space Stations and Beyond".

Session 1 Lunar and Planetary Infrastructure

Phobos - A Future Space Station
Dr. P.A. Hansson and A Bond

Strategies for Development of a Lunar Base
C.M. Hempsell

Session 2 Space Stations

The Commercial Demand for Space Stations
D.M. Ashford

European Manned Space Infrastructure - A Heretical View
C.M. Hempsell

Session 3 Propulsion Stages

An Overview of the Ariane Transfer Stage
D. Salt

Mission Capability for a High Performance Orbital Propulsion Module
Dr. E. Kruzins

A Modular Propulsion Concept For Future Space Infrastructures
L.W. Hobbs

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Exectutive Secretary.

Registration
Forms are available from the Executive Secretary. Please enclose a SAE.

27 September 1989 10.00am-4.30pm

BRITISH SOLID PROPELLANT ROCKETRY

The emphasis will be on British post-war solid propellants and the development of associated rocket motor and launch vehicles.

Papers to be presented will have the following themes:

Cordites - by E. Baker
Composite Propellants - by J. Hicks
Sir William Congreve and His Rockets - by P. Turvey
Early Rocket Motors - by V. Green
Gosling - by E.White
Sounding Rocket Motors - by J. Rolfe
IMI Motors - by S. Gordan
Stonechat - by P. Moore

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary. Please enclose a SAE.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. Membership cards must be produced.

44th ANNUAL GENERAL MEETING

NOTICE IS HEREBY GIVEN that the 44th ANNUAL GENERAL MEETING of the BRITISH INTERPLANETARY SOCIETY Limited will be held in the Society's Conference Room at 27/29 South Lambeth Road, London, SW8 1SZ on 16 September 1989 at 12 noon precisely.

Attendance is restricted to Fellows of the Society. Admission is by ticket. Those wishing to attend must apply for tickets not later than 10 days before the date of the meeting.

AGENDA

1. To receive the Report of the Council on the Society's Affairs for the year to 31 December 1988.
2. To receive the Society's Balance Sheet and Accounts for the year ended 31 December 1988 and the Auditors Report thereon.
3. To consider the following resolution:

   "That the Society's Council be authorized to raise a loan for the purpose of the proposed extension, if necessary, up to the sum of £30,000".
4. To appoint Auditors and to determine the method of fixing their remuneration. The present Auditors have expressed interest in continuing in Office.
5. To elect four Members of the Council of the Society. In accordance with Article 43, the following Members of the Council will retire at the meeting:

M.R. Fry	I.E. Smith
A.T. Lawton	C.R. Turner

If the number of nominations exceeds the number of vacancies, election will be by postal ballot in accordance with Article 44. The final date for the receipt of ballot papers will be 31 January 1990.

6. Closing Remarks by President.

By Order of the Council
L.J. CARTER
Executive Secretary

A Fellow who cannot be personally present at the meeting may appoint by proxy some other person, who must be a Fellow of the Society, to attend and vote on his behalf, subject, however, to the proviso that a proxy cannot vote except on a poll.

Spaceflight Office:
27/29 South Lambeth Road,
London, SW8 1SZ, England.

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Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery. ***Spaceflight*** binders (holds 12 issues) are available at £6.00 (US$11.00), inclusive of surface mail delivery.

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Published monthly by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by JWL, Ltd., Aylesbury, Buckinghamshire, England.

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Spaceflight
The International Magazine of Space and Astronautics

Vol. 31 No.9 **September 1989**

FRONT COVER: A scene from Apollo 15. Astronaut James Irwin salutes the US flag. In the background is the Lunar Module, named Falcon, and Mt. Hadley. *NASA*

Bush Calls for Moon and Mars Missions

President Bush has instructed the National Space Council (NSC) to draw up plans for US manned missions to the Moon and Mars. In a speech on July 20 marking the 20th Anniversary of the Apollo 11 lunar landing, Bush said: "We must commit ourselves anew to a sustained programme of manned exploration of the Solar System - and yes - the permanent settlement of space." The President did not commit himself to a 'within in this decade' time limit as President Kennedy had done when directing NASA to a place a man on the Moon.

Bush, flanked by the three Apollo 11 astronauts, addressed an audience which included NASA officials and astronauts. He told them: "In 1961 it took a crisis, the space race, to speed things up. Today we don't have a crisis; we have an opportunity. To seize this opportunity, I'm not proposing a 10-year plan, like Apollo. I'm proposing a long-range, continuing commitment.

"First for the coming decade, for the 1990s, Space Station Freedom, our critical next step in our space endeavours.

"And for the next century, back to the Moon. Back to the future and this time back to stay.

"And then a journey into tomorrow, a journey to another planet, a manned mission to Mars."

Bush acknowledged his bold plans would need the support of the US Congress which is currently threatening the future of the Freedom Space Station.

"Ten years from now, on the 30th Anniversary of this extraordinary and astonishing flight, the way to honour the Apollo astronauts is not by calling them back to Washington for another round of tributes, it is to have Space Station Freedom up there operational and underway."

The President has directed the NSC, under the leadership of Vice-President Dan Quayle, to determine "specifically what is needed for the next round of exploration: the necessary money manpower and material, the feasibility of international collaboration and to develop realistic timetables." The NSC is to report to the President as soon as possible "with concrete recommendations to chart a new and continuing course to the Moon, Mars and beyond."

NASA Administrator, Richard Truly, has transferred the Johnson Space Center Director, Aaron Cohen, to NASA Headquarters for the next few months where he will lead the agency's response to President Bush's call for details on the organization, resources and timetable needed to establish a Lunar base and send men to Mars.

"President Bush's statement of US space goals is welcome and refreshing," Cohen said.

Administrator Truly said: "It's a major effort and we should not kid ourselves - we've got a lot to do."

NASA's Office of Exploration has already conducted studies into manned missions to the Moon and Mars. An exclusive report on this work appears on p. 297.

Space Station Faces Budget Cuts

New Scaled-down Configuration Proposed

NASA officials have drawn up plans for a scaled-down Space Station in anticipation of severe budget cuts. The House of Representatives has cut $395 million from the requested $2.05 billion Freedom budget and further cuts are expected when the budget is put to the Senate. ESA, Japan and Canada, international partners in the Freedom project, are very unhappy with the proposal. If the new configuration is adopted they feel it will break the terms of the Memorandum of Understanding signed by the four partners in September of last year.

If the Space Station budget is cut severely NASA will have to abandon present plans for the Space Station and adopt a new configuration nick-named "Scrub '89".

The new configuration would see a reduction in the size of the Space Station's truss structure from 15 to nine bays. The power output of Freedom's solar arrays would be almost halved from 75 kilowatts to 38 kilowatts. (Such a reduction in power would drastically reduce the number of experiments that could be carried out aboard the station.) A thermal control system that would serve all space station modules would be abandoned and each module, including the European and Japanese laboratories, would have to have their own thermal systems. The downlink for transmitting data back to Earth would have its transmission rates reduced from 500 megabytes per second to 300 megabytes per second.

The international partners in the Space Station project are said to be unhappy with the new configuration which will increase their costs and restrict their research work when the station is operational. The launch of the European and Japanese modules may be delayed until extra funding becomes available.

The partners feel the Memorandum of Understanding signed in September last year would be breached if the new configuration is adopted. The agreement clearly stated the US would provide utilities for the other modules including the thermal control system.

Space Station spokesman Mark Hess told ***Spaceflight*** that NASA officials at the Langley Research Center drew up the alternative configuration as "an exercise to see how the programme would respond to budget cuts". According to Hess the extent of any budget cuts will not be known until the middle to latter part of September. The Senate will consider NASA's budget in early September when it returns from its recess.

Above:
Patrick Moore speaking at the British Interplanetary Society Apollo 11 Anniversary Dinner on July 21st welcomed President Bush's announcement on a Return to the Moon but expressed concern with that part of the statement which said that the purpose of the project was to re-establish US superiority in space. 'The future of space exploration', he said, 'now depended on international cooperation'.

Below:
These colour images of Neptune were taken 53 hours apart, on July 9 and July 12, by the Voyager 2 spacecraft. The image on the left was made from a distance of 41.56 million miles (67.04 million kilometres), and the image on the right from a distance of 39.5 million miles (63.7 million km). They show evidence of surprising variability in the large-scale weather patterns of Neptune. The dark oval spot is relatively constant and has been followed by Voyager for more than six months. However, the bright cloud to the north and east appears to separate from the dark spot during the 53-hour interval. This variability occurs despite the reduced energy flux available to drive the weather on Neptune, which receives about 0.2 percent as much power per unit area as the Earth and about 3 percent as much as Jupiter. These estimates include both the energy upwelling from Neptune's interior and the energy received as sunlight. The estimates will be refined when Voyager passes Neptune on August 25, 1989. The left-hand image was made with a composite of violet, clear and orange filters. The right-hand image was made with blue, clear and orange images.
NASA/JPL

Neptune's Newly Discovered Moons

Four new moons have been discovered orbiting Neptune. Temporarily designated 1989 N1, N-2 N-3, N-4, the first new moon was initially seen in images transmitted to Earth by Voyager 2 in mid-June. Its existence was confirmed upon examination of other images after the moon's orbital motion had been calculated and its position could be predicted. The discovery of three more moons was announced in early August.

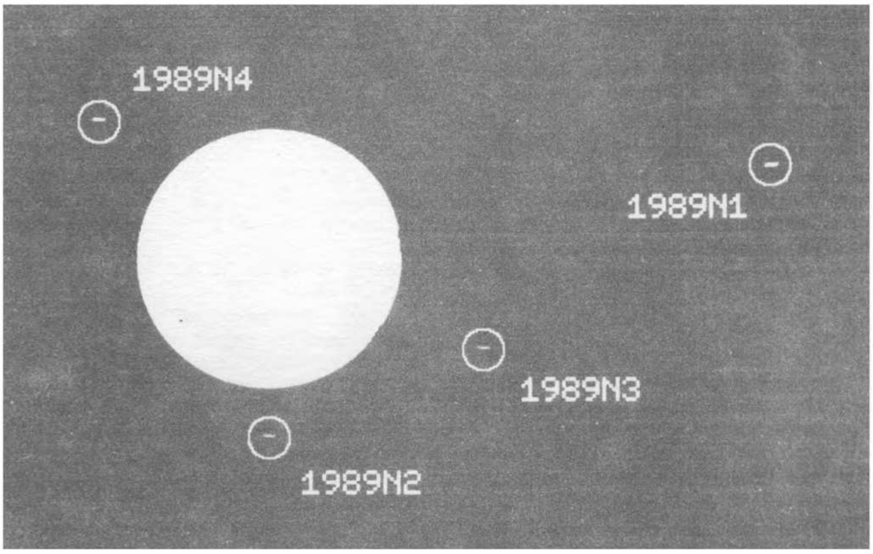
The first new Neptunian satellite, N-1 could range in diameter from 200 to 600 kilometres (about 125 to 400 miles) and orbits in a very nearly circular equatorial orbit about 92,700 kilometres (about 57,600 miles) from the planet's cloud tops or about 117,500 kilometres (73,000 miles from the planet's centre.

Permanent names will be given to the moons at a later date by the International Astronomical Union (IAU).

According to Dr. Stephen P. Synnott, a Voyager imaging team scientist at JPL, the satellites appear as small, bright smudges in Voyager pictures due to the long (46-second) exposure. Pictures taken in coming weeks will show the moons more clearly.

1989 N1 cannot be seen from Earth because the moon is so close to Neptune that the brightness of the planet itself masks the tiny point of light. Voyager 2 will continue to study the new moons and will conduct searches for others on approach to the planet. Neptune has two other known moons: Triton, discovered in 1846, and Nereid, discovered in 1949. Triton is between 2,500 and 4,000 kilometres (1,500 to 2,500 miles) in diameter; Nereid is probably somewhere between 300 and 1,100 kilometres (200 to 700 miles) in diameter.

1989 N-1 orbits well outside the orbits of the postulated ring arcs. Its existence lessens concerns about radiation hazards to the spacecraft near the planet, since the moon probably sweeps charged particles out of the area as it orbits Neptune.



Neptune's four new satellites are visible in this Voyager 2 image recorded on July 30 NASA/JPL

Galileo Probe Safe - Say Project Leaders

Top officials of the Galileo project have said there is little danger that the nuclear fuel onboard the Jupiter probe could be released to contaminate the Earth if there was an accident during launch.

"The bottom line is that the mission, as it has been designed, analyzed and tested, is safe", said John Casani, deputy assistant director for flight projects at NASA's Jet propulsion Laboratory (JPL). "Some of the reports that have been circulating in the press to the contrary are not true".

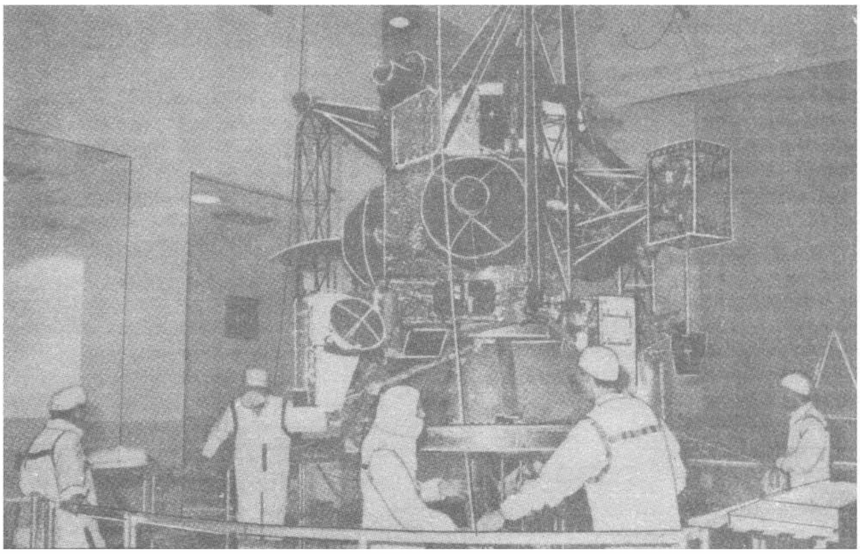
Casani said the probe's radioisotope generators (RTGs), which use plutonium-238 to produce radioactive decay that generates heat and, in turn, electricity, have been through a rigorous test program for the past eight years. The tests involved full-sized explosions representing almost every conceivable type of accident that could occur during Galileo's launch aboard the Space Shuttle Atlantis.

Galileo Project Manager Dick Spehalski of JPL said that final approval for use of the plutonium is expected by the first of September.

Galileo is expected to be launched on October 12 and started on its six-year trip to Jupiter by the crew of Atlantis - Commander Donald Williams, Pilot Michael McCulley and Mission Specialists Shannon Lucid, Ellen Baker and Franklin Chang-Diaz.

Commander Williams said he has no special reservations about the flight relating to the use of the RTGs.

John Conway, director of payload management and operations at Kennedy Space Center, said assembly and check out of Galileo have been completed and that technicians are ready to begin prelaunch processing and integration with Atlantis, which is on schedule to roll out to the launch pad on August 28.



The Galileo probe undergoes final preparations at the Kennedy Space Center NASA

Indian Satellite to Have British Pressurant Tanks

British Aerospace has received an order for six helium pressurant tanks valued at US$500,000 from the Indian Space Research Organisation for use in their Insat II satellite programme. Deliveries will be completed during 1989. Each tank will have thick titanium walls and will be manufactured from superplastically formed hemispheres which are subsequently equatorially welded.

Soviet Moon Flight Admission

Cosmonaut Valeri Bykovsky has revealed in a book that he was to have been the first cosmonaut to walk on the Moon and, if all had gone to plan, he would have set foot on the Lunar surface before Neil Armstrong made his historic Moon walk.

According to the book, entitled 'Cosmonaut No.5', the design of the Soviet Union's lunar spacecraft, Zond, began soon after the launch of Sputnik. Bykovsky says his five day flight on Vostok 5 was to prepare him for the flight to the Moon.

The Soviets were set to land a man on the Moon in 1968 says Tass. But the death in 1966 of Sergei Korolev, the chief designer of the Soviet space programme, "hampered and retarded the Lunar programme," the news agency reported.

According to the Soviet news agency Tass, the Proton booster would have been used to launch a cosmonaut into Lunar orbit. Western analysts believe a launch by Proton would have permitted a Lunar fly-by but would not have been sufficient to carry the mass of a landing vehicle. A lunar landing would have required the heavy lift 'G' booster, which failed during all three attempts to launch it.

Columbia Returns to Space

The Space Shuttle Columbia has returned to flight status after three and a half years on the ground. Mission STS-28 was launched at 8:37 EDT on August 8. Columbia was reportedly carrying a KH-12 reconnaissance satellite for the US Department of Defense. The mission was expected to end with a landing at Edwards Air Force Base on August 13. Columbia made her last flight in January 1986 just weeks before the Challenger accident.

Hipparcos Launched

Ariane V33 successfully placed the Hipparcos and TV-SAT2 satellites into orbit on August 8. The launch was slightly delayed due to a problem with the launch pad. Hipparcos is an ESA project to map out the heavens accurately.

Spanish Satellite Order

Marconi Space Systems expects to win a major order as payload prime contractor for the telecommunications payloads to be carried on Spain's HISPASAT communications satellites.

Pegasus Launch Delayed

The launch of the first Pegasus booster has been delayed until October. The launch was originally scheduled for August 22 but the maiden flight has been postponed to allow additional testing of the structure used to attach the booster to the B-52 deployment aircraft.

Japanese Launch Aborted

An attempt to launch Japan's Geostationary Meteorological Satellite-4 (GMS-4) by an H-1 launch vehicle was aborted on the launch pad. The countdown was halted on August 8 because of a failure in the first stage motor.

European Space Station Elements Renamed

The abbreviations APM (Attached Pressurised Module), MTFF (Man-Tended Free Flyer) and PPF (Polar Platform) will no longer be used when referring to the Columbus elements of the Space Station Freedom. In future the APM will known as the Columbus Attached Laboratory, the MTFF will known as the Columbus Free Flying Laboratory and the PPF will be called the Columbus Polar Platform.

Romanenko - Living and Working in Space

In 1987 Soviet Cosmonaut Yuri Romanenko spent 326 days in orbit on board the Mir space station. He has made two other space missions: Soyuz 25 and Soyuz 38. Romanenko is now managing a group who train cosmonauts at Star City. He does not expect to make a fourth space flight. During his recent visit to the UK Romanenko was interviewed by *Spaceflight:*

Yuri Romanenko.

How did you become a Cosmonaut and what sort of selection process did you go through?

We have periodic recruitments for new training groups. The process of training is quite lengthy. In 1969/70 there was such a recruitment programme. They were looking at young pilots with some experience of flying, people who could pass a medical examination and those who wanted to go into space. So when the commission studied my dossier, my height, my weight and my medical data, they suggested I went through the training. At the time I was an instructor pilot in the army. I was 25. I agreed to go through the testing. I was successful and I was admitted to the group of cosmonauts in 1970. I spent 18 years in the cosmonauts training group. In that time I was commander of a backup crew five times, three times a commander of the main crew and three times I went into space.

During your space walk from Salyut 6 in 1977 there were stories that you were almost lost in space when you left the space station without a tether. Is this true?

It was the joke of my engineer, but not everybody understood correctly, possibly it was a bad joke. In those days our space suits were attached to the station by means of a very rigid cable. In order to move and get out I had to disengage the back-up cable. When Georgi Grechko, my colleague, saw the cable unhooked and my feet going out he was frightened for my safety, he forgot about the enormous umbilical cable that was keeping me in place.

Later when you were on board the Mir space station you had to make another space walk when the Kvant module failed dock successfully?

The reason it did not dock correctly was because a bag full of hygienic towels and tissues got in the way. It got into the docking device quite by chance when a Progress spacecraft was undocking. So with the engineer Aleksandr Laveikin I had to leave the station make our way to the docking device and remove this object and throw it out into space.

Were you in any way worried about making this space walk because you had not trained on the ground for this specific operation?

We prepare on the Earth with a big redundancy capacity for any emergency. There is a whole training system which allows the cosmonaut to take decisions in space and do things that are not planned for the particular mission. So the cosmonaut is trained to do basic things that may be needed: how to leave the space station; how to service external equipment; how to behave in emergency situations, for example if somebody faints. Or if a meteorite hits a space suit, because one person is left alone, active, after and he nas got to pull his colleague back into the spacecraft, close the airlock, get the person out of his suit. We were practising this in case it happened. Practice justifies our deep understanding of the training programme.

I remember that two cosmonauts, Lyakhov and Ryumin, they had to in flight, disengage a massive radio telescope antenna. The station diameter is a bit more than four metres and they had an antenna behind them, ten

metres in diameter that had some how become hooked with the station. The cosmonauts had to go out, cut it free and then push the antenna away. Or the telescope repairs that were undertaken by Titov and Manarov on the Kvant module - they had never done it on Earth. We have the following procedure if some thing happens in orbit during a long term flight: the back-up crew reenacts it all in the pool in the hydro-laboratory to see what can be done. This process of training is filmed on video tape. Recommendations are written up and everything is sent up to the crew. The crew talks to experts on Earth and watches the tapes and gets prepared for a particular job. It saves money because you do not have to send a special crew.

How does living on board the Mir space station compare to the Salyut stations?

I would say it is considerably better on Mir. More comfortable, more thought out for long term flights. For example on Salyut we had no separate sleeping quarters. The crew would make themselves a bed on the ceiling or walls. On Mir we have two cubicles for the Commander and the Flight Engineer, where you have a bed your only little cupboard, your own little window, it has also got a communications system, we put pictures of our children on the walls, we have individual 'Walkman' type tape recorders for listening to music. Everything is a lot more spacious. There are areas for cooking, eating and exercise. We have an exercise bike that folds away when you do not need it. The design of the Mir station is a result of the practice of using the previous stations.

After your flight of 326 days we saw you carried out of the capsule. How long was it before you were back on your feet and fully recovered?

I was carried out of the capsule against my will. The landing conditions were very hard, there was a snow storm at the time. Only the best helicopter pilots were allowed to accompany the capsule down. From 4,000 metres to Earth there was zero-visibility. Our pilot couldn't see us, he found us only by the radio beacon. The doctors in the recovery team were told not to allow me to get up. I wanted to get on my feet straight away. In other flights when crews returned they could not get up and fell flat on their backs and fainted. Because the weather was so bad they grabbed me and took me straight to the helicopter. Once in the helicopter I asked the doctors to let me stand up. The doctors from the various organisations that looked after my health held a conference to decide whether to let me stand or not. They agreed to let me stand. I got up and I said: "Look at me". They were taking my pulse and looking me straight in the eye in case I was about to faint. I said: "Look at me I'm standing. How's my pulse?" It was fine. Later I got out of my space suit and got into the aeroplane which took me to Baikonur, where my wife and 12 year old son were waiting for me. I walked down from the aircraft myself and picked up my son. My wife was very worried she thought my back might break or something! But nothing happened. I walked to the bus and from the bus to the hotel. The next morning I even ran more than 100 metres. Everyone was very surprised... On the other hand there was nothing very surprising - the exercise programme was very well planned, all I had to do was follow it properly.

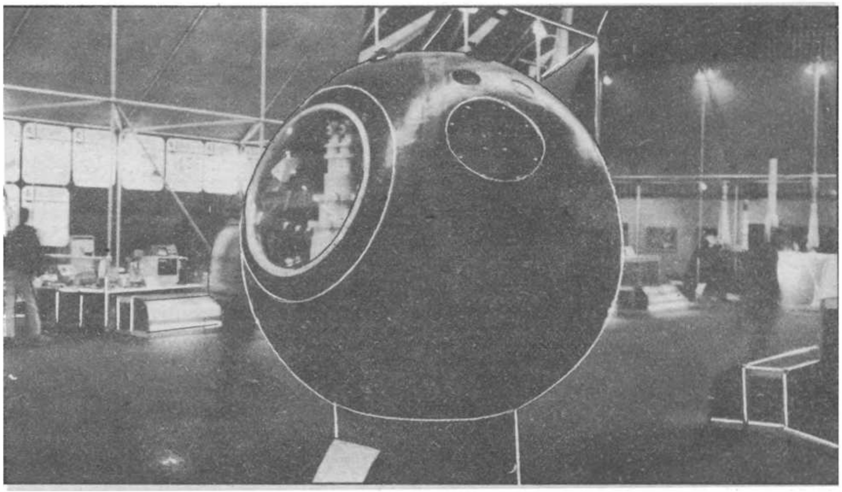
French Sign Photon Agreement

June 16 saw the signing of an agreement between the French Space Agency CNES and Licensintorg for a French experiment to be carried on a Soviet Photon satellite in the spring of 1990, *writes Jon Chappell.*

The experiment, named Crocodile, is designed by the CNET-Bagneux Laboratory and aims at producing high quality organic crystals for non-linear optics. These new materials will open up a new generation for optical processing equipment, transmitters and coherent light amplifiers, modulators and logic functions. The crystals can only be manufactured to a high enough quality under zero-g conditions because there is no thermal convection.

The hardware for the experiment was constructed by the COMAT company with CNES as the contractor. It consists of a thermostated case containing a sectioned test tube for growth of the crystals by cross diffusion.

A press conference on May 16 devoted to the results of the recent flight of the Photon satellite stated the eventual aim of the programme was the creation and industrial production of near perfect materials and biologically pure medicines in microgravity. For this work the Soviets envisage the use of unmanned satellites and also orbital stations such as Mir, the advantage of unmanned satellites being the lower cost compared with manned flight.



A Soviet Photon capsule exhibited at the Paris Air Show. *James Goddard, Science Museum*

The last mission of the Photon satellite, launched on April 26, carried experiments from CNES. The overall weight of experimental equipment came to approximately 400 kg. The descent vehicle made a soft landing in Orenburg on May 11. The equipment aboard conducted research into growing crystals, welding semi-conductors, metal and precision optical equipment as well as bio-experiments. The experiments were later removed and returned to the organisations concerned. This particular Photon capsule has been launched three times and is to be replaced. A furnace similar to the one on Photon is to be installed in a new module for the Mir space station.

For the Soviets' long term aims for the experimental and commercial production of materials in orbit, they are developing a space vehicle from the Nika series, which have an increased period of active life (up to 120 days) and a larger area of storage space for experiments weighing up to 1,200 kg.

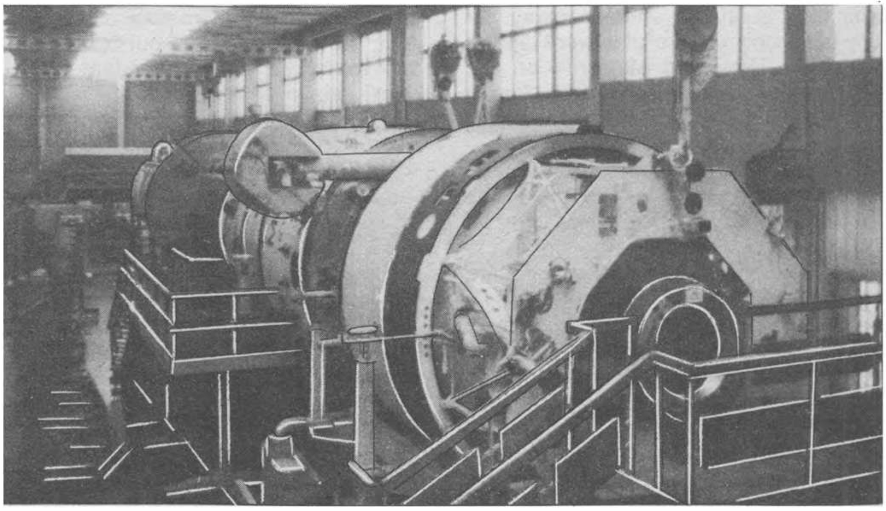
Return to Mir

Mid-September Launch for Soyuz TM-8

Soviet Cosmonauts will return to the Mir space station later this month according to ex-cosmonaut Vladimir Shatalov, Chief of the Cosmonaut Training Centre. The space station has been unmanned since April.

The Soyuz TM-8 mission was originally scheduled for launch on April 19 but postponed after the launch of the first two Salyut class modules was delayed. The mission has now been scheduled for 'mid-September' and will last 'several months'. There are two crews preparing for the flight, Commander Aleksandr Viktorenko and Flight Engineer Aleksandr Serebov and the second pair: Commander Anatloy Solovyov and Flight Engineer Aleksandr Balandin. Shatalov did not reveal which team would be the prime crew but it is widely expected to be the Viktorenko and Serebov pair.

The mission is expected to see the docking of the first two specialised modules, the testing of the Cosmonaut Manoeuvring Unit and the first use of a new space station supply craft.



A recent photo of the Mir training mock-up at Star City. Note the new module docked to the forward port, furthest from the camera. *Robert Staehle*

The New Modules

Mir's crew will receive two specialised modules, the first - the Re-equipment Module - is scheduled for launch in the middle of October. The second - the Technology Module - is expected to be launched in December or January of next year.

The new module will at first dock with Mir's forward port and will then be transferred to a radial port by means of a small mechanical arm. The Soviets may leave the module docked to the forward port until the second module has been successfully launched, this would reduce the period in which the station will be asymmetric.

New Progress Expected

A new version of the Progress cargo carrier is expected to be launched before or during the Soyuz TM-8 mission. The new Progress will be launched on the SL-16 Zenit booster. Progress 42 is expected to be the last of the present design of cargo craft. However, it is possible the final Progress mission will be cancelled and the new version used instead.

Cosmonaut Manoeuvring Unit

The Cosmonaut Manoeuvring Unit (Russian abbreviation: YMK) will be launched on board the Re-equipment module which features a one metre diameter airlock large enough for a cosmonaut with YMK to pass through. The YMK is expected to be tested during the mission by cosmonaut Aleksandr Serebov.

The Soviet Union first developed a manned Manoeuvring engine in the mid-sixties which is said to have looked like a motorcycle. The unit was never tested in orbit because Soviet space officials believed there was no need for men to work outside their spacecraft!

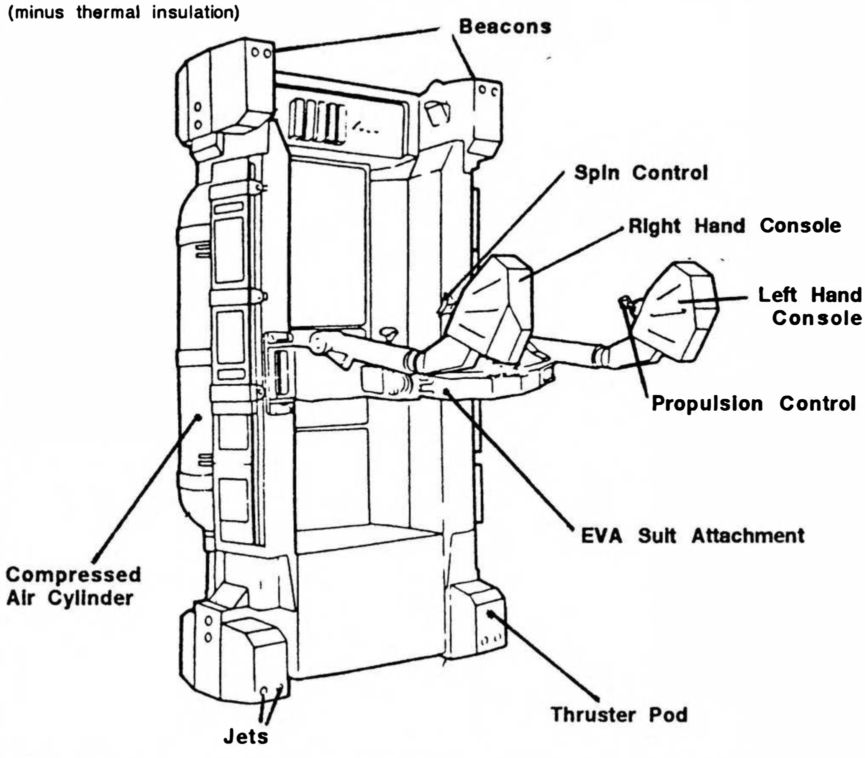
The YMK has 32 'micro-engines' operated by compressed air which, according to the Soviets, will enable the unit to 'perform the most complicated operations'. Cosmonauts will be able to fly the YMK for periods of up to six hours.

The Soviet say the YMK is a safe and reliable unit because of the "duplication of each vital system: electrical power, propulsion control, actuators." The propulsion and orientation jets of the unit can be operated in either semi-automatic or direct control mode. The semi-automatic manoeuvring can be used in either propellant-saving or boosted mode.

During the first on-orbit tests the YMK will remain tethered to the station as a safety precaution. The tether is about three millimetres in diameter and is strong enough to prevent Serebov flying off into space should a malfunction cause a jet to fire continuously. Cosmonauts dislike the tether as it will interfere with the YMK's movement, making it difficult to handle. The tether will limit the range of the YMK to 60 metres. Untethered a cosmonaut will be able travel about 100 metres from the station.

The YMK will undergo a rigorous series of tests during Soyuz TM-8. The unit is designed so it can be donned without the assistance of another cosmonaut or special equipment. Serebov's first exercise with the YMK will involve moving five to eight metres from the airlock and then back. If further tests prove successful Serebov will fly the YMK along the entire length of the Mir complex.

The YMK
(minus thermal insulation)



NASA's Plans for Manned Missions to the Moon and Mars

We live in momentous times. We have the ability to send humans into the inner solar system within a decade or so, to begin a sustained sequence of voyages and establish the outposts which will gain a foothold on other planets. The President of the United States has announced that to be the nation's goal, after a hiatus of 20 years. While we certainly could have already achieved a Lunar base and manned Mars landings, the will was not there because the announced goal of Apollo was met: it was a political achievement, and it had met its ends. The goal of permanence in the expansion of homo sapiens into space did not exist, and thus neither did the programmes to achieve it.

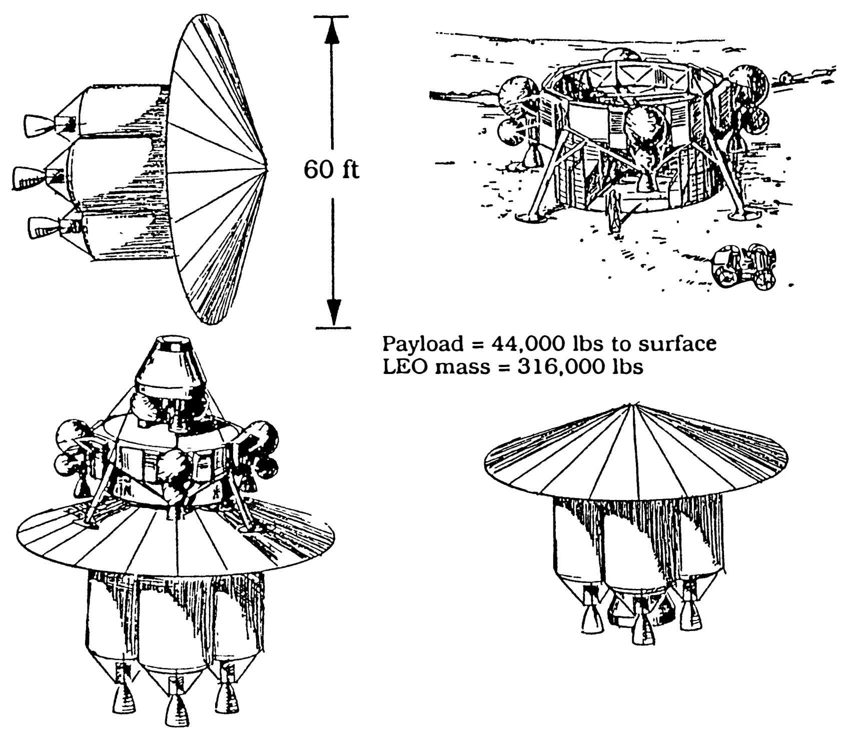
While the Apollo era Moon landings were a huge achievement, all of it was done with expendable equipment. We had chosen that as the least risky approach. In contrast, studies NASA has been performing in the last two years are based on permanence as a prime requirement, and this results in markedly different approaches, vehicles and technology. Since we now have a definitive goal, these studies will be used as some of the material for defining the new programmes. Some of the salient features of these studies are discussed in this article, with the cautionary note that they are not to be taken as hard conclusions or definitive trade results.

There are a number of major issues that bear discussing: Where should we go, why, and in what sequence? At what rate, and to do what? How? What about use of extraterrestrial materials? What technology has the highest leverage and why? Do we need a heavy lift launch vehicle?

While the answers are not clear in all areas yet, there are some "emerging conclusions":

There are many potential destinations in the solar system, but in practical terms we must go either to the Moon or to Mars, as all other places are too inhospitable, limited, or too far away at this time. Of these two, Mars must really be our "ultimate" goal. The path to Mars could be direct or via a permanent Lunar presence, but the end result by the 2020 time frame must be a permanent outpost on Mars as well as one on the Moon.

Lunar Transfer, Descent and Ascent Vehicles



By Ivan Bekey
Special Assistant for Systems Engineering,
Office of Exploration,
NASA Headquarters

It is inconceivable that we would emplace an outpost on either body and totally abandon the other, for they are totally different and each worthy in its own right. Mars because it is a relatively hospitable planetary laboratory with an atmosphere and perhaps a life record; and the Moon because it is the closest source of extraterrestrial materials and a laboratory for learning to live and work away from Earth. However, if our aim is to set up a permanent base of extraterrestrial operations as soon as possible, the Moon is the only place that is a candidate.

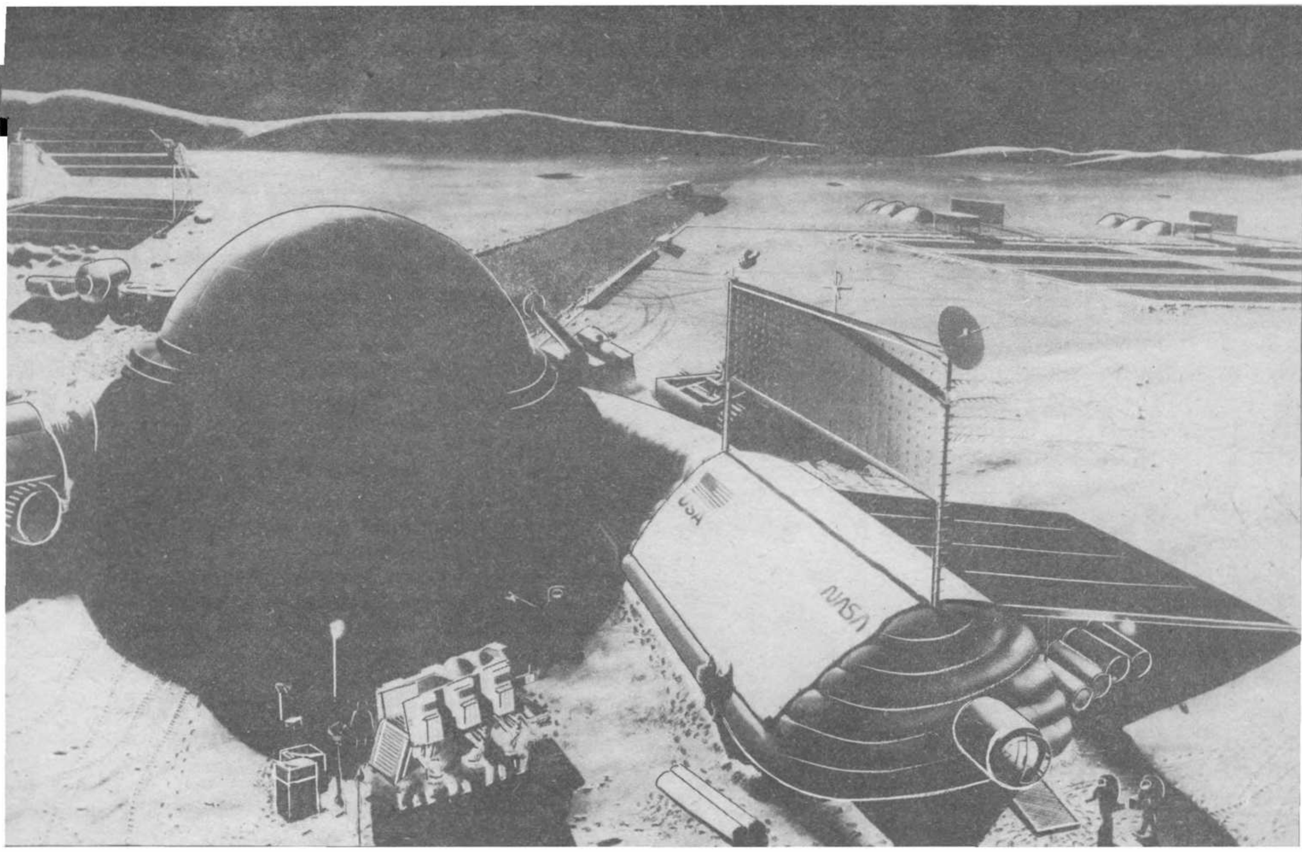
President Bush made this path clear in his July 20, 1989 speech, setting the Lunar outpost as the first step, to be followed by a Mars outpost, and later trips beyond.

A Lunar Outpost

The setting up of a Lunar outpost requires a decision as to what is its main purpose. Science and the tending of instruments is of course feasible and desirable, but may not make a good case by itself. The mining and utilisation of Lunar materials might make a good case, if we knew what we wanted to do with the stuff. Four such options have been now studied, making and exporting propellants, using the materials in the building of the base itself, making Solar Power Satellites for energy export to the Earth, or mining Helium-3, and taking it to Earth for use in fusion reactors.

Whereas in the past it was thought that there was leverage in mining oxygen on the Moon and bringing it to low Earth orbit for fuelling transfer vehicles, it now appears that it probably does not make much sense to do that. The reasons are that the costs of transport to LEO from the Earth are a small fraction of the costs to transport mining and processing equipment to the Moon and then exporting propellants to LEO. Thus the break-even time is bound to be very long.

Furthermore, the total cost to bring propellants from the Earth to LEO for a Lunar mission are small compared to the total costs of the mission. Thus reducing the cost of Earth-orbit transportation has little leverage. But there may well be leverage in using the propellants for "local" transport - that is for



The completed Lunar Outpost. *NASA*

round trips between the Moon and Lunar orbit, rather than bringing them from Earth. This is analogous to buying potatoes grown locally rather than imported from thousands of miles away - all other things being equal, the extra costs for the long range transportation will make the product more expensive and noncompetitive. And, of course there are many benefits to having a source of oxygen locally available for breathing purposes.

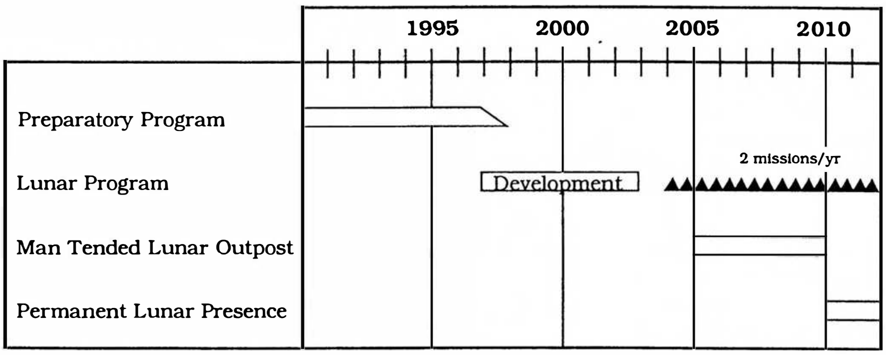
The business of using extraterrestrial materials for constructing pieces of the outpost itself are probably valid, but only for far future large growth outposts and bases. But analyses have shown that the Lunar soil could be readily processed to make building materials for large Solar Power Satellites, and that 90-95% of their mass could be so supplied. Since such satellites are likely to have masses in the order of tens if not hundreds of millions of pounds, a huge mass savings would result. This would not only aid in the economics but avoid a serious environmental concern due to Earth-orbit rocket exhaust contamination of the upper atmósphere. However attractive this technique may be, there is not yet an acceptance of Solar Power Satellites for energy delivery.

One of the most intriguing reasons forestablishing a permanent outpost on the Moon could be to mine Helium-3 from the surface, and send it to Earth for use in fusion electrical power generation. At the current rate of progress, the Department of Energy nuclear fusion programme foresees commercial fusion reactors in 30 years, a time scale commensurate with Lunar bases and the ability to undertake large scale mining operations.

Use of Helium-3 rather than the conventional Tritium would make these reactors much cleaner, and cut one decade off their time table. This is because the Helium-3/Deuterium reaction produces primarily protons, not neutrons as does the conventional Tritium/Deuterium and thus is 3 orders of magnitude more benign in radioactivation of the machine's structures. Commercial amounts of Helium 3 do not exist on the Earth, however, the isotope is plentiful on the Moon.

A NASA workshop last year concluded that it is feasible and may be economically viable to mine the Moon for Helium 3 to supply virtually all the electrical power needs of all nations on Earth, with supplies adequate for millennia to come. This is the subject of a NASA chartered task force which is almost complete in its analysis of the op-

Lunar Gateway Overview



Missions 1-4
Establish Beachhead

- Secure temporary habitat
- Begin power and thermal systems setup
- Deliver construction equipment
- Setup simple astronomy, geoscience

Missions 5-8
Establish Outpost

- Deploy and outfit large habitat
- Perform early bioscience and astronomy
- Complete power and thermal systems setup

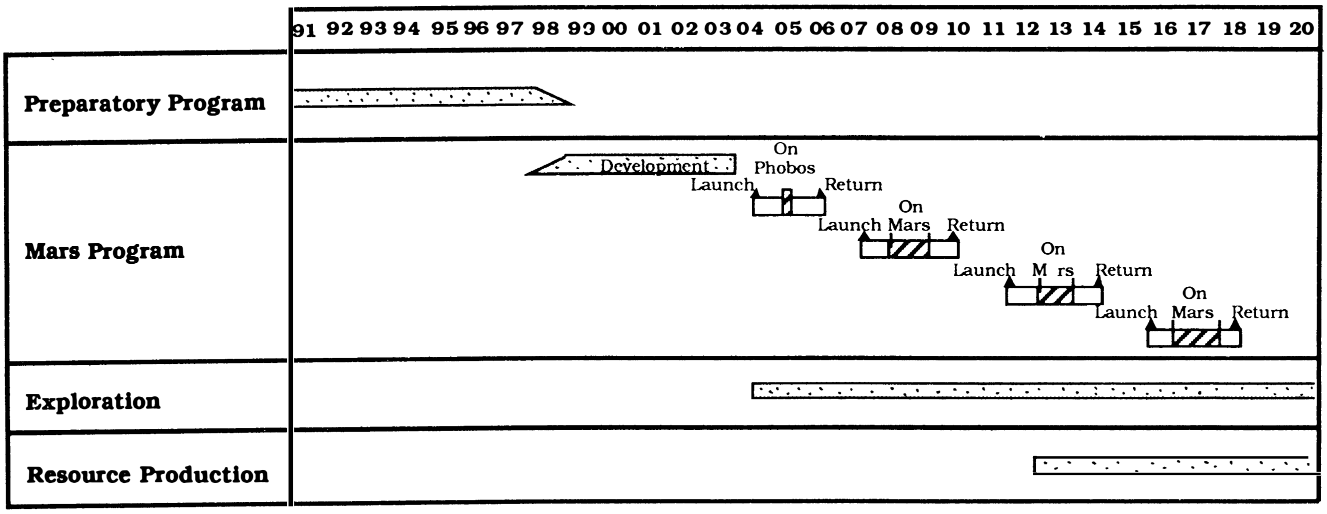
Missions 9-12
Outfit Outpost

- Deliver and setup resource production demonstration
- Full scale astronomy
- Bioscience

Subsequent Missions
Resource Production

- Propellants production
- Deliver and setup nuclear plant
- Setup vehicle servicing facilities
- Large science construction

Mars Gateway Overview



MISSION #1 PHOBOS	MISSION #2 MARS	MISSION #3 PHOBOS AND MARS	MISSION #4 PHOBOS AND MARS
■ 3 crew	■ 5 crew	■ 5 crew	■ 5 crew
■ All-up Opposition/Venus flyby	■ All-up conjunction	■ All-up conjunction	■ All-up conjunction
■ Forward deploy hab. module to surface	■ Land at previous surface site	■ To Phobos and surface (new site)	■ To Phobos and surface
■ Teleoperated surface rover, sample return. Science	■ Surface science, exploration	■ Surface science, exploration	■ Surface science, exploration
■ Phobos propellants research/ demonstration		■ Install Phobos propellants manufacture plant (1/2)	■ Complete installation of Phobos plant

portunities this represents for commercial ventures in space. Thus mining of extraterrestrial materials on the Moon may well have a meaning "close to home" in the everyday lives of billions of ordinary citizens.

Even if the economic arguments for all these cases were weak, we must learn to mine and process local materials if we are ever to move toward self sufficiency in space, and eventual independence from Earth.

With respect to the "when" question, it would seem that there are no obstacles in technology, since we have already voyaged to the Moon six times 20 years ago. But the boosters, spacecraft and launch and checkout facilities are gone. We could rebuild them with current technology and that should not take more than 10 years, even without a crash programme as Apollo. However, if we want to establish a more permanent presence, such as a Lunar base or outpost, many if not all the infrastructure and transportation should be reusable rather than expendable, for both long-term costs and reliability. (One does not fly across the ocean in a jet transport and discard it after one flight!).

The establishment of a reusable transfer vehicle, permanently based in space and moving cyclically between Earth orbit and Lunar orbit is one such device. In order to minimise propellant needs, aerobraking upon Earth return has been shown to be really advantageous, reducing the propellant load 50% compared to all-propulsive vehicles. This aerobrake, in order to be lightweight and perhaps deployable, must be developed and tested in Earth orbit. The technologies of Lunar soil mining and its benefits must be developed and proven. These could add a few years to a Lunar programme. However, properly phased, there is no reason why we could not return to the Moon about the year 2000, but this time to stay.

In this spirit an evolutionary Lunar outpost programme was defined, with first landing in 2004. The strategy was to emplace both science and materials processing equipment on the Lunar surface in a phased approach. This resulted in an orderly buildup of capability on the surface, beginning with a space station derivative habitable module, and expanding to an inflatable habitat within two years. Nuclear power is emplaced after 2010, while depending on solar cell arrays until then for all of the outpost's needs. The advent of the nuclear power source at 2.5 megawatts enables startup at the materials processing facility.

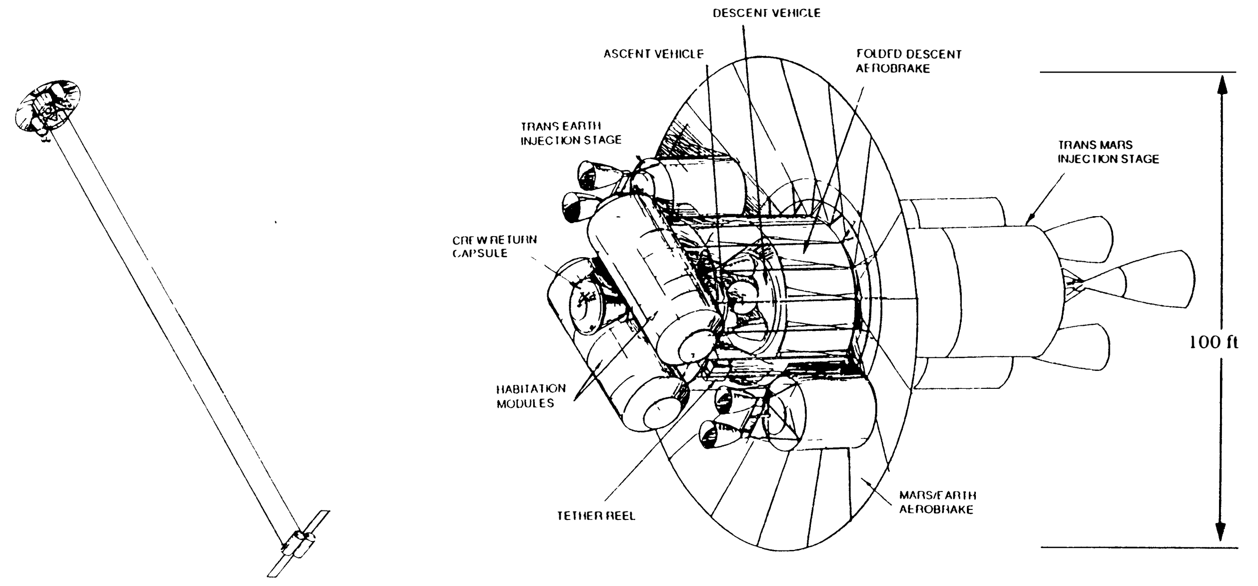
The vehicles that would carry crews and cargo between Earth and Lunar orbit, and between Lunar orbit and the Lunar surface are illustrated on p.294. They are seen to be functionally similar to the Apollo spacecraft, with a transfer vehicle that is based on the Space Station Freedom an shuttles between it and Lunar orbit; and a second vehicle optimised for round trips between Lunar Orbit and the Lunar surface. The vehicles can carry a cargo package or a crew capsule, each weighing 20 MT. These vehicles were defined a being totally reusable.

Manned Mission to Mars

A Mars programme was also defined, in which the emphasis was to emerge with a smaller scale of activities than emerged in past Mars programme definitions, both for reasons of cost and simple practicality. Past manned Mars mission designs have, for the most part, been characterised by very massive spacecraft. The masses in Earth orbit have tended to range from 1,500 MT to upwards of 2,500 MT, depending on the type of trajectory taken and on the mission design parameters.

The parameters and trajectories in this study were chosen to minimise the initial mass in Earth orbit; allow ready evolution from an initial modest step to full Mars surface operations; and take advantage of a new heavy lift launch vehicle concept, the Shuttle Z.

Mars Spacecraft



The first mission was to Phobos to minimise the complexities and mass of the undertaking, but the systems were designed so they could be used for a Mars surface landing with little change. The impact on Space Station Freedom was kept low by minimising the amount of on-orbit assembly at the expense of requiring larger launch vehicles. The investment rate was minimised by keeping the mission rate low.

One of the findings that emerged from this study is that it is possible to go to Phobos with a maximum Initial Mass in Low Earth Orbit (IMLEO) not very different from the minimum required to go to the Martian surface. This requires that the Mars surface trip occur using conjunction trajectories and taking about three years, while the Phobos mission can use the much faster opposition/venus flyby trajectory to minimise the risk for the early missions yet not driving up the mass requirement.

Another result noted is that with the proper designs, the evolutionary "track gauge" can be set at vehicles weighing about 600-700 MT IMLEO, and used for going anywhere in the Martian system. A mission sequence was chosen in accordance with these findings, and is shown on p.299.

Phobos First

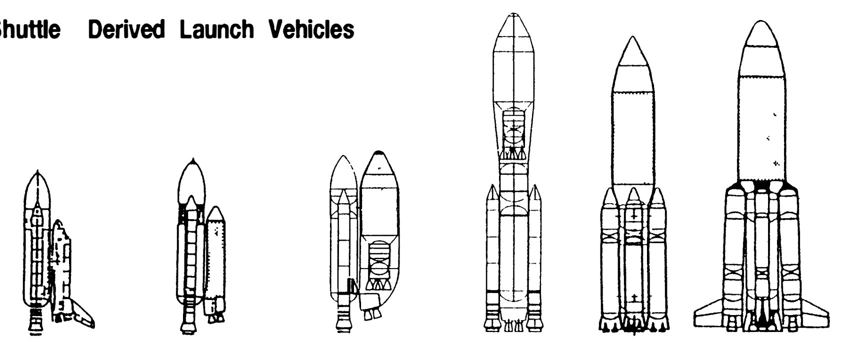
The first mission is to Phobos with 3 crewmen in a vehicle designed for 5. It uses an opposition trajectory with Venus flyby. It lands an empty landing vehicle on the surface of Mars to serve as a backup habitat for the second mission. It also deploys teleoperated rovers to the surface, which return a surface sample to the mother ship at Phobos. It performs Phobos science, learns how to operate at 0.001 g, and demonstrates the setup and operation of a pilot plant for the production of cryogenic propellants from Phobos soil. It returns after about one month at Mars.

The second mission goes to the Martian surface using a conjunction trajectory to maximise efficiency. It carries a crew of 5 and lands at the site of the first habitation module. The crew performs science, explores, prospects, and spends about one year at Mars. There is about one year between missions.

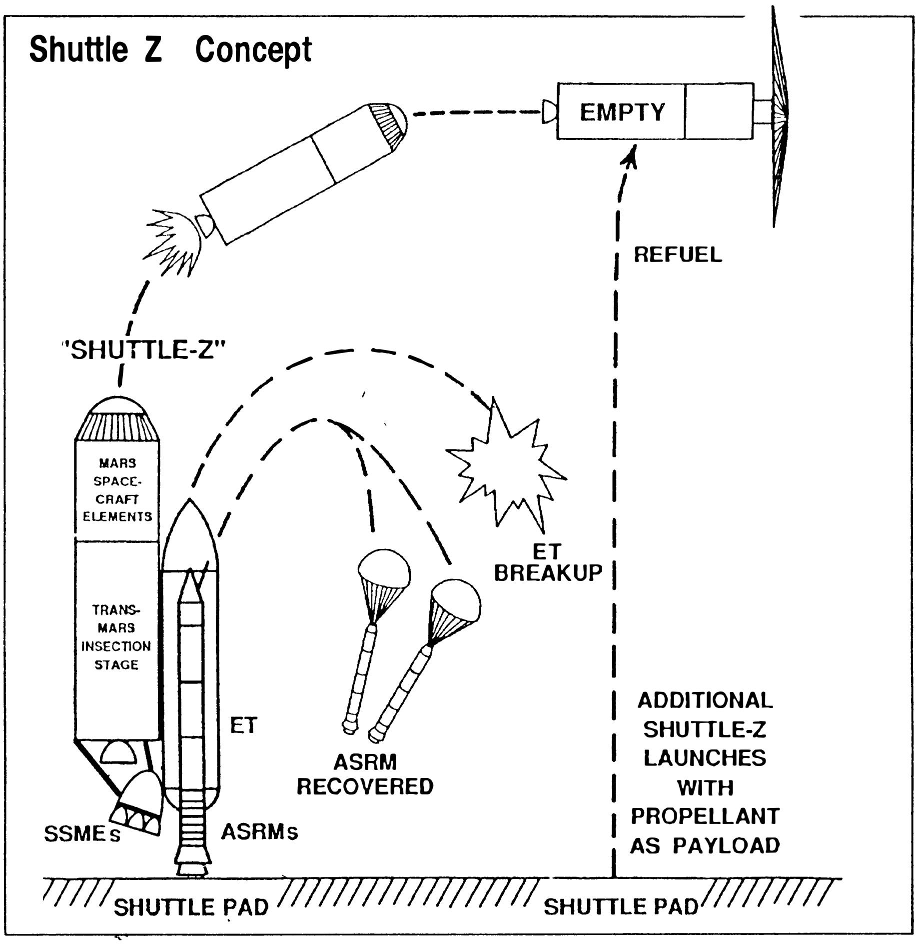
The third mission goes to both the Martian surface and to Phobos, where the crew erects the first half of a propellant production facility. It also uses the conjunction class trajectory. The fourth mission emplaces the second half of the propellant plant, readying the Mars infrastructure for a sustained series of visits during which a permanent outpost will be set up.

The evolutionary nature of this sequence is made possible with nearly constant mass requirements due to the choice of trajectories and the design of the vehicles for their ultimate capability needed, even if they will be initially underloaded.

Shuttle Derived Launch Vehicles



The vehicle design centres around a tethered configuration to provide artificial gravity at very low rotation rates, in order to avoid the effects of microgravity on the crew. This vehicle is illustrated on p.300 with the Earth departure transfer stages attached and with the stages jettisoned in the spinning configuration while underway. While its total mass is just over 700 MT, its dry mass is 113 MT without the trans-Mars injection stage. With the dry stage the mass is 154 MT, which represents the largest mass that would have to be launched by any launch vehicle.



Shuttle Z Concept

Shuttle Z

Analysis of both of the above programmes show that launch vehicles which can place at least 70-100 MT in orbit per launch will be needed for practical Lunar missions, and which can place 154-250 MT in orbit per launch for practical Mars missions. This is in order to reduce the scale of activity on Earth and in the space assembly and checkout "node" to a practical degree.

It is not necessary to develop an entire new vehicle for such capability. Since the vehicles will be used rather infrequently, say a few times a year, a satisfactory vehicle would have low development cost by virtue of being a modification of an existing vehicle, and reasonably low operations cost be virtue of being an add-on to an existing fleet. An unmanned shuttle-derived vehicle fills this bill well.

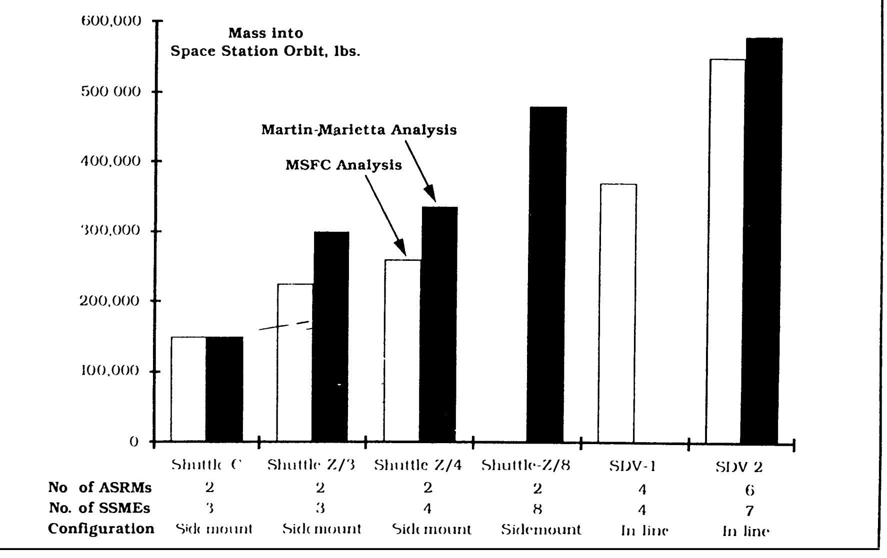
In this spirit a new shuttle-derived launch vehicle concept has been defined by the author, and called the Shuttle-Z. It is based on the realisation that Lunar and Mars (as well as planetary, geostationary orbit, Molniya orbit, or other high energy) missions which depart from low Earth orbit all have as a part of the space vehicle a large propulsive stage with which to provide the required velocity to transfer into the desired trajectory. Heretofore the total "payload" to be launched into orbit by a booster vehicle was always taken as the combination of the spacecraft and this transfer stage. Since the gross weight of a Mars or Lunar chemical transfer stage must be 4-5 times as large as the "spacecraft" itself, the requirements for the launch vehicle capability were seen as very large.

The Shuttle Z concept, illustrated above, consists of the dual use of this spacecraft transfer stage operating also as a booster third stage. In the Shuttle derived vehicles, it would function on top of a Shuttle stack, with the non-propulsive parts of the Orbiter replaced by a shroud holding the stage and the spacecraft. In operation, the basic vehicle is deliberately overloaded so as to burn out at a suborbital velocity. The transfer stage is then burned to depletion, supplying the rest of the velocity to reach orbit. The resulting mass in orbit is much greater than could have been orbited by the basic vehicle alone, and is attained by expending during ascent to orbit all the propellants the spacecraft normally would use to transfer from orbit to the desired high energy trajectory.

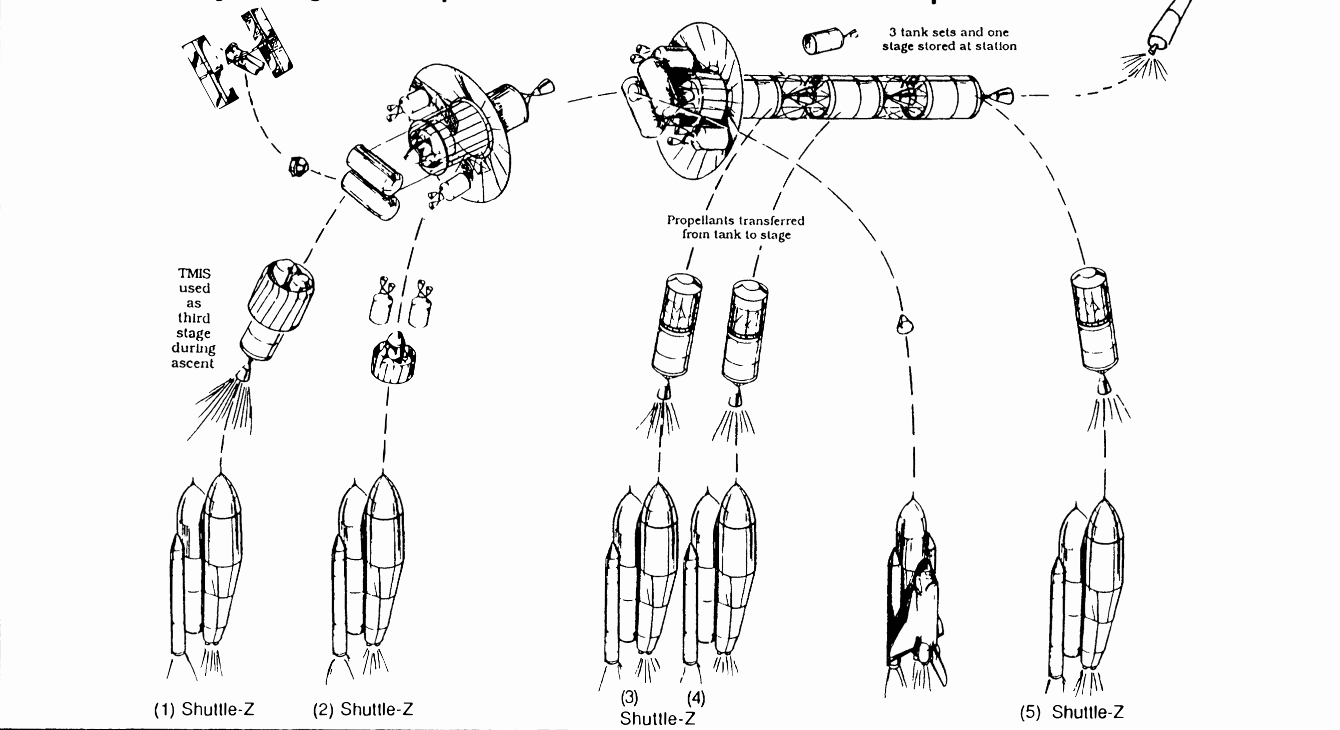
The next step is to launch one or more identical Shuttle Z launch vehicles except with propellant tanks as their payload, rendezvous and dock with the spacecraft in Earth orbit, and refill the tanks of the transfer stage. This refilled stage is then burned to gain the velocity needed to transfer to the Moon or to Mars.

The net effect of the above integra-

Performance of Shuttle Derived Launch Vehicles



Mars Gateway Integrated Spacecraft/Launch Vehicle Concept



tion of the space vehicle and the booster is in essence to create a "dual-use upper stage" which is both a part of the spacecraft and a part of the booster. Since the transfer stage must be procured as part of the mission spacecraft, the "upper stage" of the booster is "free".

Preliminary analyses forecast impressive performance for such Shuttle-Z vehicles: A shuttle derived vehicle with its normal complement of two advanced solid rocket boosters, a strengthened external tank, and three Space Shuttle Main Engine (SSME) engines would be able to lift a Mars spacecraft and stage weighing 113-137 MT (250-300,000 lbs) to orbit if the Mars transfer stage is burned as a dual-use third stage. This is almost double the payload capability without the upper stage.

If four SSME engines were used, the payload capability would increase to 125-150 MT (275-330,000 lbs) with the engines at only 100% thrust, and to 137-164 MT (300-360,000 lbs) with the engines at 109% thrust. Two pods of four engines each could be used, one on each side of a beefed up external tank. This would involve considerably more development, as the basic vehicle must be modified to support the two thrust structures, and the launch platform modified to open a second flame opening and sound suppression system.

While it is clearly less desirable to do this than to use one 3-engine boattail from the Shuttle, the upper estimate of the capability of such an 8 engine Shuttle-Z would grow to about 230MT (500,000 lbs). Vehicles in this heavy-lift class might benefit from in-line configurations and would probably be more practical with multiple solid boosters, even though the commonality with an operating shuttle fleet would be reduced and the development cost would increase. these vehicles are illustrated on p.300, with their performances on p.301.

The smaller of these shuttle-derived vehicles, which we call "Shuttle-Z", could operate from the Shuttle launch pads and orbit the entire Mars spacecraft fully assembled and checked out in a single launch, or at most two. The required propellants for the Mars transfer would be then lifted with 3-5 identical Shuttle Z vehicles operating with filled propellant tanks as the payload to perform the tanker function.

Thus we could obtain a system that can send a crew to Mars with at most 5 launches of a Shuttle-derived vehicle and on standard shuttle for the crew. This operation is illustrated above. The development costs would probably be an order of magnitude lower than for a new launch vehicle, and the cost per flight not very different than for a Shuttle but with 4-6 times more payload. That would imply about 1,000 $/lb or less, a perfectly acceptable launch cost for infrequent operations.

The Shuttle-C or the Advance Launch System (ALS) would meet the requirements of Lunar vehicles with at most 2 launches per mission. Though smaller in mass, traffic of several flights a year steady state are expected in the operations phase of a Lunar outpost.

The Shuttle-Z concept can also be used for unmanned planetary, geostationary, or other high energy missions. In each case, the payload will be greatly increased compared to use of the spacecraft/stage in the conventional manner. The willingness to burn the transfer stage to depletion on arrival in Earth orbit, and its subsequent refuelling, greatly increase the mass delivered into the final destination. As examples, a 3 engine Shuttle-Z with a third stage the same size as the Mars transfer stage would place 74MT (163,00 lbs) into geostationary orbit. Or 62MT (136,000 lbs) could be sent to Saturn on a Cassini-type mission, just as two examples of its mind-boggling capability. In fact with Shuttle-Z we would have, for the first time ever, the capability to orbit heavier spacecraft than we could probably afford to build!

This article has attempted to discuss some of the issues, problems and potential solutions of the Lunar and Mars missions we will undertake in the first decade of the next century. While we have an enormous amount of work to do yet, we are further along in understanding how to carry out these missions than we were at the time President Kennedy committed us to go to the Moon. And we will voyage again soon.

Selecting the British Astronaut

Air-Vice Marshall Peter Howard is responsible for the selection of the first British astronaut who will fly to the Mir space station in 1991. Spaceflight interviews Peter Howard to gain an insight into the long and complicated selection process. Since the interview took place 150 astronaut candidates have begun medical examinations at a BUPA Medical Centre in London.

The first four of the 150 would-be astronauts tested at the BUPA Medical Centre on August 7 (Left to right) Dr Keith Waldron, Juanita Lofthouse, Philippa Bland (BUPA Fitness Assessment Unit physiologist/coordinator), Mary Roberts and Sue Robertson BUPA

Can you tell me how you became involved in the Juno project?

I had a career in the Royal Air Force at the Institute of Aviation Medicine, Farnborough, which I finished up commanding for a number of years. That gave me two things which I think have been valuable to me for this project: the first is research experience and secondly it gave me experience managing major projects such as this. So I have the management experience and the scientific background. How I got into it is somebody asked if I was interested and I said yes. I am also a member of the ESA medical panel which led to the nomination of the first European astronauts, the first five of whom were tested at Farnborough with very similar tests to the one the Russians are now specifying for our man. So I have some experience in the medical requirement of space flight.

There were over 12,000 phone calls to your astronaut hotline. How many callers received an application form?

I do not know the exact figure, but over 6,000. A larger number of callers eliminated themselves on the initial questions. We had people of 78 and seven ringing in saying they want an application form and a large number of people who were within the age group but did not have the science qualification, so they were excluded. About half of the people who rang in got an application form. I believe so far about 4,000 have been returned.

Have you been able to determine the type of person who has applied?

I have not seen the forms yet. I am starting tomorrow. MSL, the recruitment agency have gone through them and put them into three piles, the 'very goods', the 'totally unacceptable' and the 'don't knows'. My job is to go through the acceptable and the 'don't knows', trying to sift that down and pick out 200 of the best. We want to put 150 of them through the first part of the programme. We will interview the 200 on a telephone conference, because some of those whose application forms were very good will turn out to be inarticulate or what ever. We think by talking to 200 we will get 150.

What sort of qualities are you looking for in these people?

Personally I'm looking for somebody young. We put the age group from 21 to 40. I should be very surprised if we do not get a very large number of people under thirty into the programme. Quite clearly the criteria was stated in the advertisements. You have to have a science, engineering degree or a medical degree, although I think doctors are not really agile enough for what we want.

This is not primarily an exercise to fly a British astronaut. The object of is to carry out British scientific experiments in space and it is right and proper that they should be conducted by a 'Brit' and in my view a young 'Brit'. So the guy has got to have some scientific knowledge and people with a PhD in theoretical physics are not good candidates. We want somebody who can use his hands. Someone who is able and experienced in the use of delicate scientific equipment. The guy who is not going to drop a micro-pipette or break an iron bar with his bare hands. He has got to be fit because he has to meet the medical criteria set by the Russians.

He has to have at least the ability to speak a foreign language and to learn a foreign language quickly. I think quite a large number of people who have written in have a little Russian, some of them are fluent. If they can speak Russian then clearly that is an advantage. If they cannot it does not necessarily debar them. If they are totally word blind it does, if they are incapable of speaking any foreign language at all, then that does knock them out. The reason I said that they do not have to speak Russian is that when they get to the Soviet Union we understand the first few months of training consists of an intensive course in Russian. That is really to give them the ground work and then for the next year of course they will be totally immersed in Russian culture. So they will learn the language very quickly if they have the aptitude.

I do not give a hoot whether it is a man or a woman. It does raise complications however. The Russians, we are told, although we need confirmation, will expect the final two to be of the same gender. Now if we get down to the final four and two of them are men and two of them are women we are not presenting the Russians a choice of two from four, we are presenting either or. So we would have to have one or two candidates up our sleeve.

The 150 candidates who survive the screening process will be subject to medicals, what exactly does this involve?

It is exactly the sort of thing that major

companies use for their top executives. They expect to screen them once a year to check that their directors are not drinking too much or eating too much fatty food or things of that type. It is a fairly stringent fitness test looking at heart, lungs, liver and brain function. They have to walk on a treadmill and have their electrocardiograph (ECG) done. In conjunction with that they will under go quite a lot of phychological testing, which will involve such things as intelligence and reasoning power, plus a few specific psychomotor tests, like hand-eye coordination and motor balance to make sure that they are not totally ham-fisted. We are not necessarily looking for somebody with an IQ of 190. The thing that I emphasise when I am talking about this programme is that we are not looking for supermen. We are looking for 'Mr Ordinary' with special qualifications. Just as if you want to choose an airline pilot there is a very large pool of the population that meets the standard requirements, so I believe it is true for this astronaut. It is not for the elite, it is a job for a young man with the right qualifications.

How will you reduce the numbers after the first medical examination?

It is my guess that it will reduce itself, because if you put a largish group of people through that kind of medical 30% of them would demonstrate some degree of abnormality. You would find something the matter with them. It may be that they have a perfectly normal ECG but just occasionally there is a flip beat of no great sinister significance at all but cause for exclusion from this programme. So about 50 of the 150 will be eliminated on the medical results. With the remaining 100 it becomes a matter of judgement and balance. If we say for example the normal range of blood pressure for this age group is between 120 and 140, the guy who has got a blood pressure of 122 scores better than the guy who has a blood pressure of 138 because he is closer to what was regard as the normal, rather than the normal range. The same thing is true of a lot of other medical parameters in particular the psychological ones. I will mention the example of IQs. If he has an IQ of 65 then you throw him out, but if you have the normal distribution of IQ in the population you would like somebody who is not at either extreme. The same is true of the other tests if they are particularly adept at using thejr hands you might wink at the fact they have a blood pressure of 130. So it is largely a question of juggling all the variables and coming out with 30 people at the end of that who we think are worth testing further. The aim at that stage will be to say that other things being equal everyone in this 30 has a chance of flying.

That 30 then go through a second phase of medical and psychological testing which is much more intense. One reason for dividing it into these two phases is that the second phase of testing involves procedures that you certainly could not justify on a large population. For example you would not want to expose 150 people - most of whom will not be selected - to X-rays of the complete spine, because the radiation dosage is unethical. There are things like examinations of kidney functions which involve X-rays and injections into the veins and long term follow-up. Y ou would not want to do that on a large number of people. It would be unethical, also expensive and time consuming. So those 30 will go through that stage and also go through much more intense psychological testing as well with very specialised tests some of which were specified by the Russians. The Soviets have a whole battery of tests and although we have some flexibility over that we must obviously meet their requirements as far as we possibly can.

Out of the 30, again by the process of collusion between the doctors and psychologists, we get the number down to 15. , Again the medicals will reveal, for example, a stone in a kidney - it happened to one of the French astronauts in the ESA programme, it was tiny but cause for exclusion. So that 30 will be sifted down to 15, maybe 12 but I would hope 15. The final 15 will then go through the dynamic test programme which the Russians specify and which is eminently sensible in my opinion. That involves testing on the centrifuge to make sure they can withstand the dynamic stresses of take-off and landing, altitude exposure, just incase there is a decompression and rotational accelerations to make sure their gyros do not topple too easily and they don't get motion sick, although there is no correlation between motion sickness and space sickness. I reckon that if we put 15 into that part of the programme we will get 10 or 12 out with a clean bill of health.

The final stage will then be to select four out of the ten whose names can be presented to the Russians for discussions. Now the way in which we plan to do that is exactly the same way as you make appointments for any other responsible senior position. You have a panel of people with a wide range of disciplines, middle-aged, all experienced in their craft, all experienced in interviewing for top jobs and you sit them down and wheel the candidates in and you talk to them for half an hour and ask them questions, just like any other selection board. If you do that with any host of people whose qualifications are impeccable upon paper you all ways finish up with saying well he has got all the right things but I don't really think he is the man for the job. So consensus will produce a rank order amongst the ten and the top four will be put to the Russians. Now that does several things for us, first of all and most importantly, it gives us a bit of an insurance policy: if the Russians do not like any of the four we can wheel in our back-up team and see if they like any of them. Secondly, if the Russians select the two and one of them chickens out for some reason or gets run over by a Russian bus or whatever, we have got a back-up we can send.

Probably early next year, although the Russians want it to be November, they will go off for training in the USSR. As I have said the first few months will be intensive Russian language training and then they will go into the full programme. There comes a stage when we lose our back-ups, because although in the first three or four months if something goes wrong we can field another team quickly, once they get four, six, eight months into the training programme there is no way anyone can catch up. So once we get that far we are committed.

Of the two who go, one will be the prime candidate and one the back-up and that will not be known until the end of the training programme, probably not until two days before the flight. The guy who is left behind will carry out exactly the same pattern of experiments on the ground as his mate is doing them in space. We are going to have a ground based laboratory near Baikonur - at Baikonur I hope - where we will do the same experiments under 1 G as the other guy is doing under weightlessness, at the same time of day and that might be important, especially for some of the biological ones.

Will the rigorous testing of the final group of 15 take place in the UK or the Soviet Union?

It will be carried out here down at the Institute of Aviation Medicine at Farnborough, because that is the only place in the UK that has a human centrifuge. Having said this we know perfectly well that when our two get to the Soviet Union they are going to be put through very much the same sort of procedures again. It has been suggested to me that perhaps we should not bother with the centrifuge bit, which is difficult, expensive and unpleasant. My answer to that is I would rather know that they are alright before they go than have the Soviets ring me up and say 'hey your guy's just failed'. We have got to be sure in our

own minds that we have got guys who are going to be fit for the task. The other side of that is if the Russians ring me up and say your man does not reach the centrifuge requirements, I have documentary evidence that he does. I am not suggesting they would be difficult but it is possible.

You mentioned the British astronaut might not travel to the Soviet Union in November as originally planned.

It depends on what sort of waivers we can get. You see our selection programme as currently planned will not finish until the first week in November, maybe even the second week. Then there has to be discussions with Glavkosmos about the candidates. Glavkosmos will have to have access to all the medical records of those chosen and that will take them a day or two to sort through. Of course until that is done we will not know who the final candidates are. The arrangements for getting them to the Soviet Union will have to be made. You cannot say on Sunday afternoon 'yes we've decided it's you and you report to Heathrow Airport at three o'clock on Monday morning'. There has got to be a little gap and we are busy negotiating with the Soviets on how late we can actually leave. Because let's face it the entire selection programme is extremely time intensive. To do the whole thing in nineteen weeks flat is going to be a major achievement.

Will the British astronaut have medical experiments carried out on himself?

Yes. Professor Wolff has had a fairly large number of experiments suggested in a wide range of disciplines which mainly fall into two groups, the material sciences and the life sciences. He has established two peer groups of eminent scientists to look at these experiments and to pick out from the proposals first of all those which are scientifically worth doing and secondly those which are mechanically and logistically capable of being done. For example, if you say I am interested in discovering Maxwell's Demon, for this I need a box nine metres square, it may a jolly good scientific experiment but it is just not on, because you just have not got that much room. Some of those experiments will be physiological, there is no doubt. One or two are quite simple, like if I rotate my body through 180 degrees in a weightless state does my pulse rate change? It will mean observations by the astronaut himself and if we can get collaboration, which I think we can, on observations of a similar kind on the guys who are already there, the Mir residents.

.Would-be astronaut, Mary Roberts, is encouraged by Soviet cosmonaut Yuri Glazkov during tests on the treadmill. *BUPA*

During the training period will the two astronauts stay in the Soviet Union for the entire 18 month period?

That is for negotiation. The French man, Chretien, actually went back home on a couple of occasions for a sort of holiday break. We have to negotiate: do these people come back and if so how often and at whose expense. Or do we send the families across to visit them or do the families go and live in Russia: Space City is a big place with lots of accommodation. If the family does stay over there it means the wife and children, if there are any, will have to immerse themselves in a foreign culture as well. I think what will happen is they will go across there and come back every three months or what ever, for a few days.

I will have to pop across to the Soviet Union every couple of months or so, for a few days, to see what they are doing to our chaps, to keep abreast of the medical records in the USSR and really to collude with my Russian colleagues. So I shall be their doctor in effect.

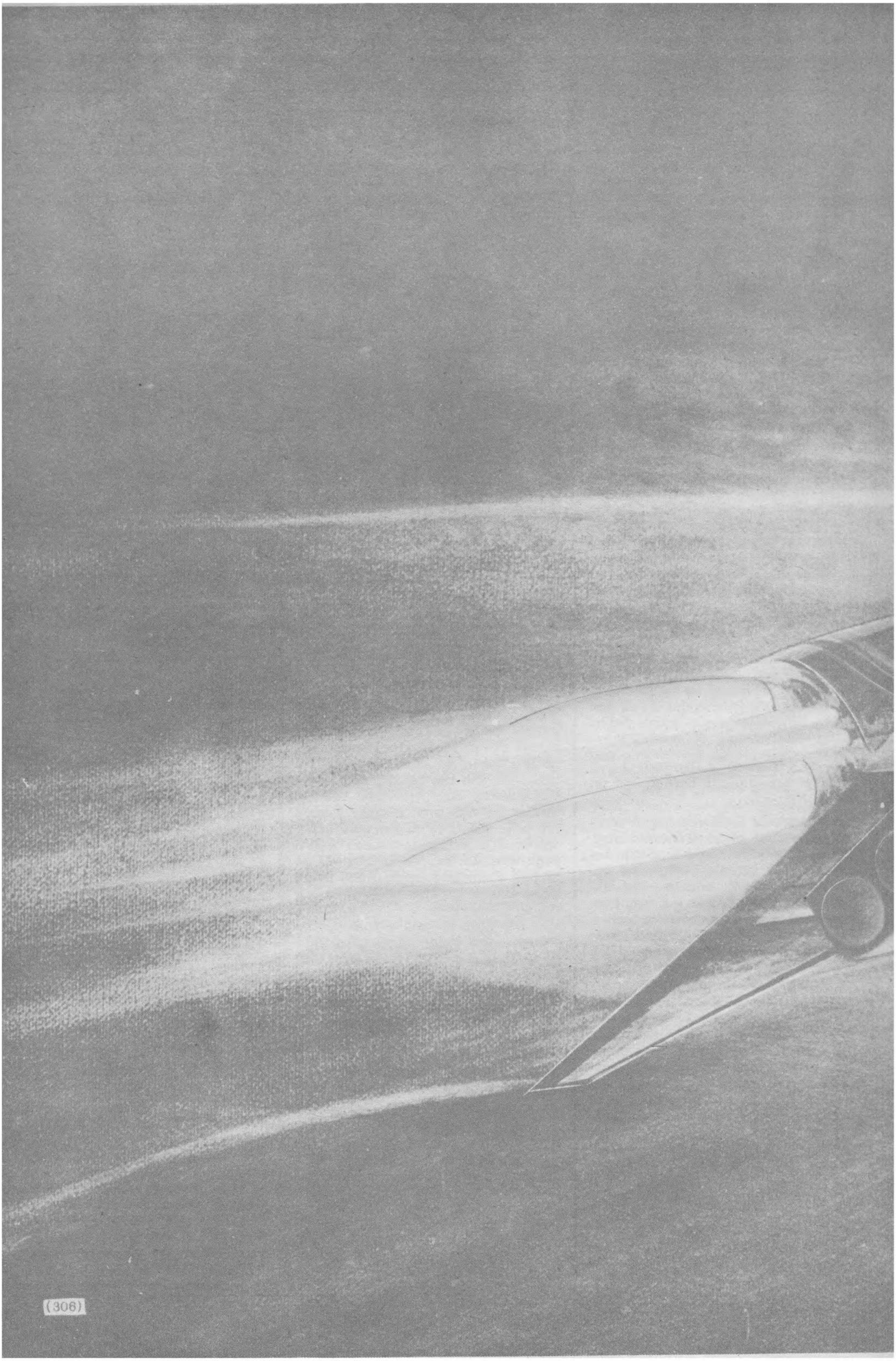
At what point will a Soviet crew be appointed to the mission?

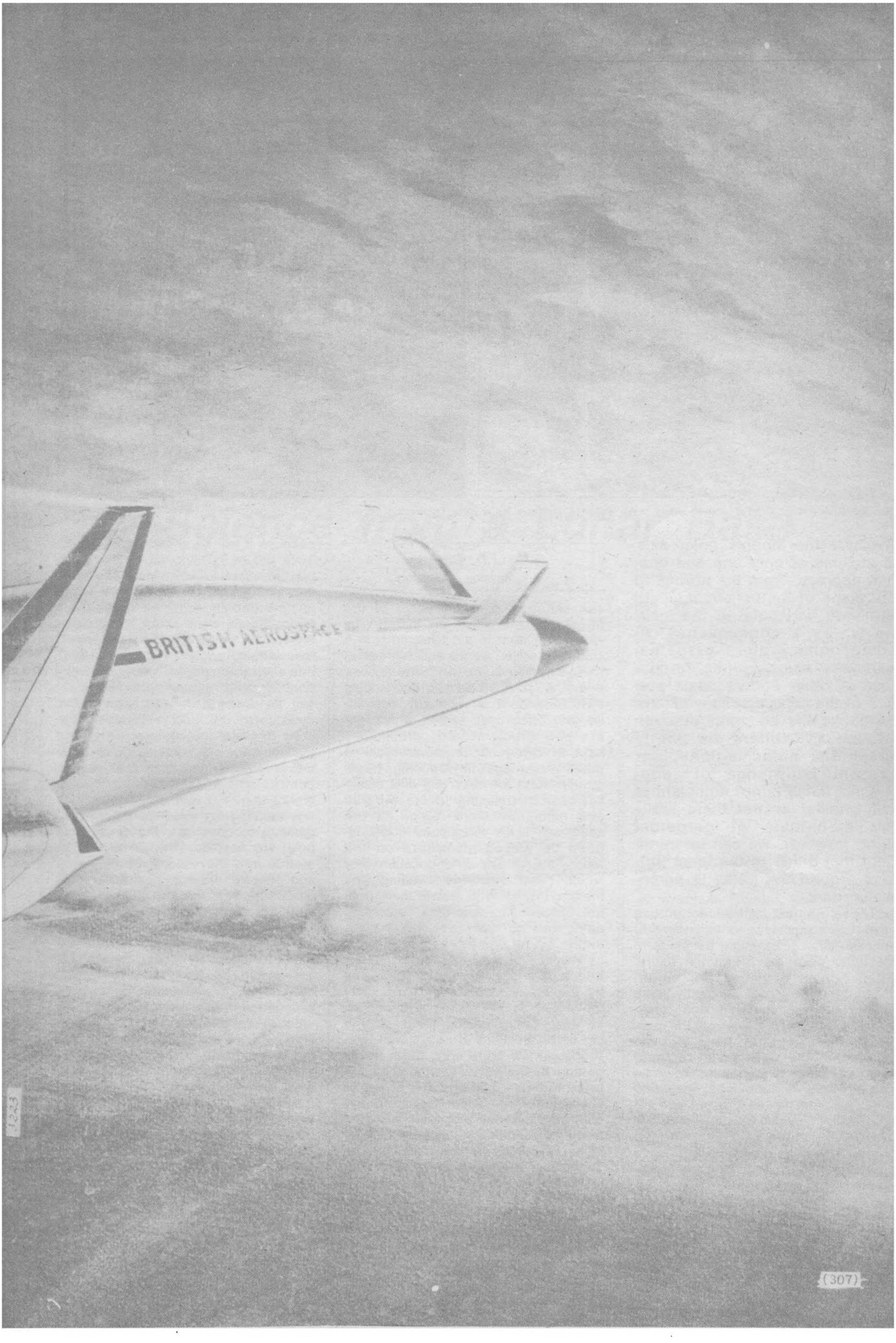
We do not know. It is not like the American space programme where they train as a crew. We know they have got a pool of cosmonauts and I think that they will behave towards that pool much the same way as they will behave towards our two and really at the last minute say 'OK it's Vladimir and Ivanovich', rather than any of the others. So we do not really know how much chance there will be for our lad to get to know the guys he is flying with. That is relatively unimportant in this case because it is not like Shuttle. It is more like you reporting Heathrow for a flight to Paris and you do not know who is on the flight deck. In effect on the way out and the way back this guy is a passenger. He is of course going to have some training in space flight systems just in case something goes wrong. I take a simplistic view of this: I think his role in the spacecraft will be much the same as a very uncomfortable flight to Paris and in the same way that you are supposed to know where your life jacket is, how to do your seat belt up and what will happen when the oxygen mask falls down, so our man will have a knowledge about the space craft systems but he will not be expected to fly the vehicle. He will travel from Earth up to Mir in the company of the commander and the flight engineer just sitting there. His other colleagues will be the people who are already aboard Mir. We do not know yet how many of those there will be, but the chances are they will have been up there some time. So in effect he will be introduced to strangers. It is unlikely he will have met them before. He spends a week onboard and then flies back.

New Space Plane Engine

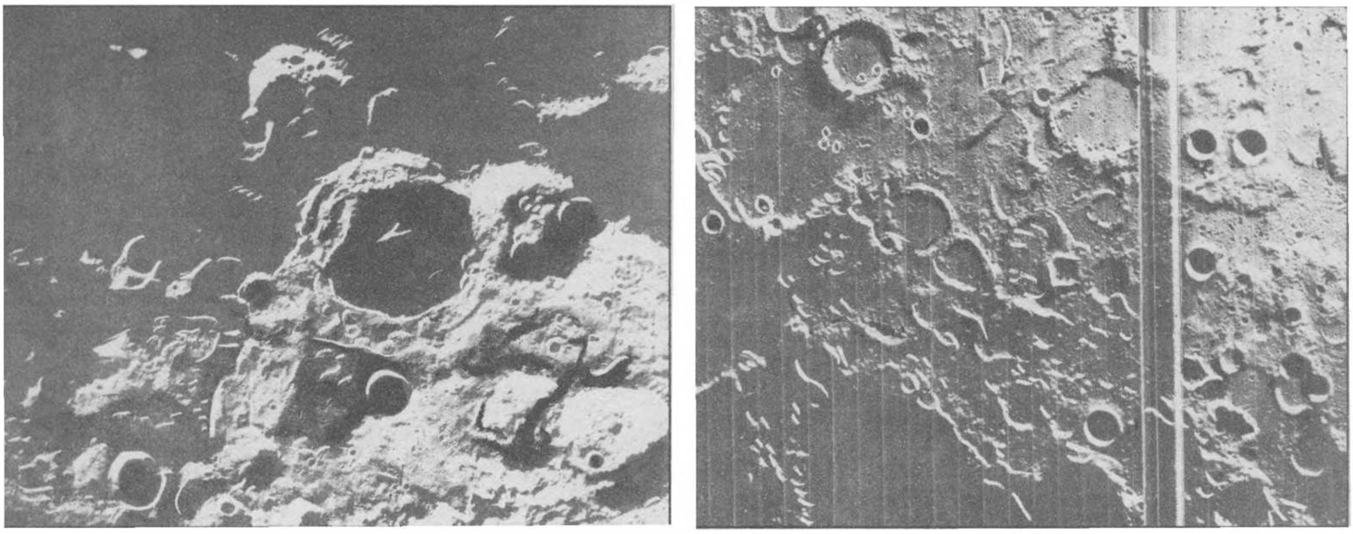
Alan Bond, inventor of the revolutionary HOTOL engine, is working on a superior engine called Satan. According to reports in the press he hopes to establish a company to develop the new engine and eventually market it. The engine would not necessarily be confined to powering HOTOL.

Centre Pages - The latest artist's impression of the HOTOL space plane. *BAe*




BRITISH AEROSPACE

Lunar Observatories



The two lunar poles, pictured above, would make excellent locations for a lunar observatory

Because the Moon's polar axis is inclined at only one and one-half degrees from the normal to the plane of the ecliptic,sunlight is nearly horizontal at the lunar poles. As a consequence, in some polar craters perpetual darkness exists, while on the rims of other craters some portion of the solar disc may always be above the horizon. Although two Lunar Orbiters did photograph the polar regions, our present knowledge of topographic detail is not sufficient to tell whether or not there really are mountains of perpetual light; however, we can be confident that much of the lunar surface around the poles is perennially dark.

By J.D. Burke
Jet Propulsion Laboratory

These unique natural conditions have led scientists and engineers to consider what uses might be made of the lunar polar regions in the future, when human activities are established upon the Moon. For many years people have speculated and made theoretical calculations about the possibility that ices may have become trapped in the dark polar regions, where ambient temperatures may be below 40 K. If such ices, including water ice, are indeed present and recoverable in useful quantity, they will provide a source of hydrogen that could greatly stimulate lunar base development. Until a properly-instrumented spacecraft goes looking for the ices, their presence or absence will remain unknown. However, enough is already known about other aspects of the polar regions so that we can seriously consider some of the things humans might do there. Why would one want to put telescopes in a cold dark crater, where one can see at most only half of the sky? The answer is that, in such a cold and unchanging environment, it is relatively easy to imagine telescopes whose entire optics and structures are permanently kept at cryogenic temperatures - a great advantage in reducing background noise for observing cool celestial objects radiating in the infrared and millimetre-wave region of the spectrum. Such telescopes could indeed be placed elsewhere on the Moon, but at any other location they would need elaborate shading and thermal insulation to isolate them from the Moon's two-week-long, scorching days and its two-week-long, frigid nights.

Visibility of less than half the sky from a polar site is partly compensated by the ability to stare uninterruptedly for as long as one wishes at any object in view. Long, uninterrupted observing times are hard to obtain with telescopes in low Earth orbit; Earth keeps getting in the way. That is why the International Ultraviolet Explorer spacecraft was placed in synchronous orbit, and it is why proposals for some newer spaceborne telescopes call for high orbits. Clearly such orbiting observatories are the correct next step in space astronomy; Moon-based telescopes are a logical follow-on.

Since we will at first probably be limited to one lunar polar observatory, not only because of funding but also because it will be wise to gain experience before building more, the question arises as to which pole should be first site. Based on the lunar topography pictured above, so far as the Moon is concerned, there is not much difference; both poles are located in heavily-cratered, ancient highlands. Thus the choice (unless a future exploring spacecraft gives us some surprise) can be made based on astronomical considerations. Astronomers are likely to prefer the south pole because the southern sky contains many interesting objects, including the galactic centre, and is less thoroughly explored than the northern sky.

Assuming an intent to place cryogenic telescopes near the south lunar pole, the next question to be considered is how they should be emplaced and operated. Since most lunar-base proposals call for low-altitude habitats, the observatory might be more than a thousand kilometers from the base. (Arguments can indeed be made for placing the base near a pole for reasons having nothing to do with astronomy. The unchanging thermal and illumination environments provide many engineering advantages. However, here we are assuming that those arguments have not prevailed.) The first logical step, analogous to what is done in siting observatories on Earth, is to verify the site's suitability using a small telescope. At first glance this might seem unnecessary on the Moon, because there is no atmosphere. However, some known lunar effects deserve attention and a site survey might turn up others presently unknown. One phenomenon that must be considered is the small, electrostatically-suspended dust layer

discovered by Surveyors and Lunokhods (*Spaceflight*, 19, No.10, 363-366, 1977). This dust layer, a few metres deep, appears to be associated with terminator passage (Sunrise and Sunset on the Moon). Since at the poles the terminator is always nearby, the dust may always be present there. If on the other hand it is a transient effect caused by terminator movement, polar dust may be absent. Probably the only way to tell is to land an instrumented spacecraft, and this could also be the carrier for the small, automated site-survey telescope.

With a site survey completed, and assuming its result positive, it will be necessary to plan the installation and operations of the first set of observatory instruments. Since these will be largely automated or remotely-controlled in any case (not only due to the high cost of human activities on the lunar surface but also due to the need to isolate the instruments from disturbances and heat sources), perhaps they should be delivered and set up by automated means, either from orbit or by surface transport. In the present state of development of robotics and automation this does not look very practical, though it may be more so by the time when a lunar base is operating. The other option is to land or transport humans to the observatory site - a dangerous and difficult process if the base is many hundreds of kilometres away. Arguments of this sort lead to the conclusion that a lunar polar, cryogenic observatory may not become a reality until well into the age of lunar settlement. Nevertheless, a cold infrared and millimetre-wave installation offers such splendid astrophysical prospects that ultimately it is likely to become an important component in a complex of radio, interferometric, optical and high-energy observations on the Moon.

Acknowledgement
The research described in this article was carried out by the Jet Propulsion Laboratory, Californian Institute of Technology, under a contract sponsored by the National Aeronautics and Space Administration.

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James D. Burke is a member of the technical staff in the spacecraft systems engineering section at JPL. A long-time advocate and manager of lunar exploration activities at JPL, he is currently a member of a team helping to define precursor flight missions and ground-based research leading toward renewed human exploration and eventual settlement of the Moon.

Science from a Lunar Base

By Dr. Carl B. Pilcher
Acting Director, Science Division,
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Manned space flight since Gagarin and Shepard has been motivated mainly be politics, not science. Apollo is a case in point, launched in response to Soviet space successes and American international failures, most notably at the Bay of Pigs. Yet the Apollo data, despite the programme's premature demise, form the foundation of modern lunar science.

Politics will dominate a decision to return humans to the Moon, but the scientific potential will be even greater than Apollo's for we will be returning to stay. A permanently occupied lunar base will not only allow us to build on Apollo's scientific legacy, it will open new windows on the universe and on forces that influence life on Earth.

A lunar base would be a staging point for Apollo follow-on geologic field studies. Some investigations might take humans to far reaches of the Moon; some might be done through telerobots operated from the base or from Earth. The wealth of gathered samples could be screened in a basic lunar analytical laboratory, the most valuable being sent to Earth for detailed study.

Geologic studies would also clarify the history of impacts that have scarred the lunar surface and, perhaps, modified life on Earth. The lunar maria contain a record of impacts over the last 3-4 billion years. It is widely believed that the demise of the dinosaurs and other great terrestrial extinctions were caused by enormous impacts. If so, we might find a correlation between those extinctions and the rate of lunar impacts, which would have a profound effect on our views of how life evolves.

The Moon is also a valuable platform for studying distant stars and galaxies, the rest of the solar system, and Earth itself. The Moon's airless, seismically stable environment is ideal for a large array of optical telescopes that would yield incomparably sharp pictures of distant galaxies. An array of radio antennae on the lunar farside could yield a very-low-frequency view of the universe, unhindered by natural and artificial radio noise from Earth. An infrared telescope, naturally cooled in permanent shadows at the lunar poles, would have exceptional sensitivity for observing dust and molecular clouds.

Instruments on the Moon could measure the solar wind while lunar telescopes and Earth-orbiting satellites observed terrestrial auroras, helping us understand the interactions of Earth with its interplanetary environment. Lunar-based study of Earth itself could be an important complement to satellite data.

Lunar soils once on the surface, but long since buried by lava flows and impact ejecta, may preserve a record of the ancient solar wind to which they were exposed. Excavation of these soils would provide glimpses of the ancient Sun, improving our knowledge of stellar evolution and the history of the Sun's influence on Earth. Lunar materials currently exposed to the solar wind may be a storehouse of hydrogen and other volatiles for use by lunar explorers.

The Moon is also a natural laboratory, for example, for measuring the effects of partial gravity on humans and other organisms. It may also be well suited for fundamental physics studies such as measuring the proton's lifetime and the neutron's electric dipole moment.

The establishment of a lunar base would thus open a rich array of opportunities spanning many of the disciplines of modern science. The resulting advancement of knowledge could be profound.

The Author
Dr. Carl B. Pilcher was born in New York City in 1947. He received a Bachelor's degree in chemistry in 1968 from the Polytechnic Institute of Brooklyn, New York, and a Ph.D. in chemistry in 1973 from the Massachusetts Institute of Technology. From 1973 to 1985 he was on the faculty of the Institute for Astronomy and the Department of Physics and Astronomy at the University of Hawaii, conducting astronomical studies of the solar system and participating in NASA's space flight programmes as a member of the Imaging Science Team for the Galileo mission to Jupiter. He served as Guest Professor at the University of Vienna, Austria. In 1985 Dr. Pilcher accepted an appointment as a Mid-Career Fellow at the Woodrow Wilson School of Public and International Affairs of Princeton University. He received the Master in Public Affairs degree from Princeton in 1987, and spent the following year as a Visiting Fellow at the Woodrow Wilson School doing research on the history of the European space programme with support from the MacArthur Foundation. In 1988 Dr. Pilcher joined the Office of Exploration at NASA Headquarters where he serves as Director of the Science Division.

Optical Observations of Geostationary Spin Stabilised Satellites

By A.B. Giles and K.M. Hill

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Most people are aware that low-Earth orbit satellites are commonly visible to the naked eye. In fact it is difficult not to see one within a few minutes on a dark moonless night. Until recently it seems that very few people had seriously considered the visibility of Geostationary Earth Orbit (GEO) satellites, since they would clearly be much fainter than those in a low orbit. In June 1986, however, an article appeared in *Sky and Telescope* which discussed the location and observation of GEO satellites which has no doubt inspired others to try and find some of these objects. It certainly set us thinking!

Although our University's one metre telescope is primarily used for serious optical photometry of X-ray sources we decided to try and find the Australian communication satellites Aussat A1 and A2. Aussat A1 was launched by STS 51-I on August 27, 1985 and A2 by STS 61-B on November 27, 1985. Aussat A3 was launched by Ariane on September 16, 1987 and we have also recently found this satellite.

All these spacecraft are examples of the Hughes HS376 design and are almost identical externally except for the despun antenna section. Initially we were attempting to find the satellites for curiosity value only but the whole idea gradually became much more interesting. We first found Aussat A1 on February 25, 1987 and were a bit disappointed that it was fairly faint at about magnitude 14.

At about this time the now famous supernova 1987A had occurred and a semi-regular monitoring programme of this object started using the observatory's high speed photometry facility. As a temporal calibration a small LED near the phototube was driven from a pulse generator. It occurred to us, however, that a spinning geostationary satellite such as Aussat might provide an excellent and 'permanent' flashing calibration standard in the sky. We only expected a small amount of modulation due to any asymmetry in the outer surface of the satellite as it rotated. At the time we were unaware of the exact details of the outer surface or the spin rate, but we only needed a small modulation as we expected to have to accumulate many minutes of data to detect the spin. The idea was that this would make a good test comparison for the difficulty we expected in finding the earliest optical evidence for a pulsar in the new supernova remnant.

Features of Spinning Satellites

Imagine our surprise when on our first attempt to use the fast photometry system on April 4, 1987 we found Aussat A1 very much brighter on the TV screen with the 1.1 second spin modulation visible in real time on the computer display of count rate against time. The spin modulation was so evident that the satellite visibly pulsed in comparison to ordinary stars as they drifted past on the TV screen.

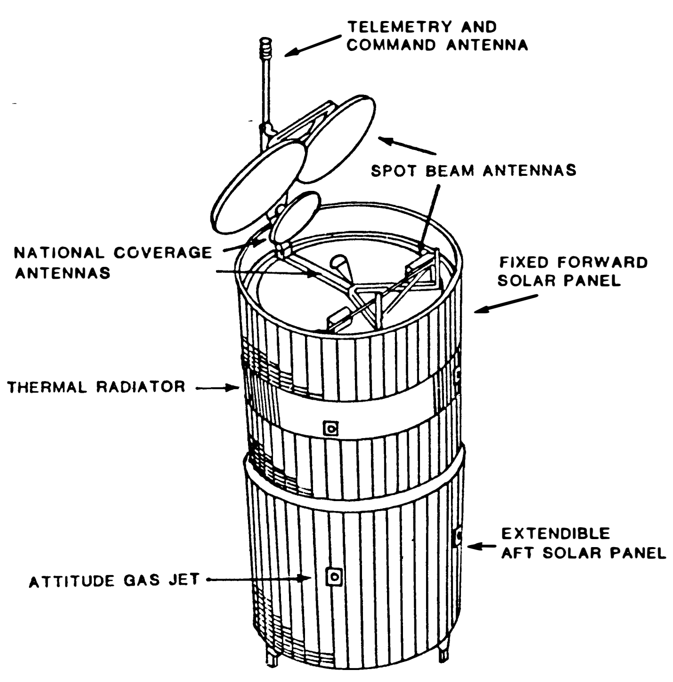
A useful way of examining astronomical objects for periodic variability is to obtain what is called a Fast Fourier Transform (FFT) of the sequential intensity measurements. This is a relatively simple mathematical process that takes place in the computer which can then display the frequency spectrum of the temporal variability. A quick-look FFT on only eight seconds of data showed very sharp features so we accumulated a lot of numbers even though we were not quite sure what was going on. We also found Aussat A2 and it was showing very similar brightness variations.

Enquiries rapidly revealed that the frequencies detected in the FFT were related to the distribution of solar cells on the outer surface of the satellites. Further observations were prevented by a long run of bad weather and a full Moon, but when we finally returned to the telescope some three weeks later we were disappointed to find Aussat A1 back in its faint state and apparently not flashing. Subsequent analysis on extended data sets has revealed no modulation at all when in this dim 'off' state. Our original aim for a permanent calibration source has not therefore been realised.

When in the bright 'on' state the sharpness of the spikes in the FFT is exceptional compared to more conventional astronomical objects. This sharp definition in frequency space immediately suggested that we were looking at an effect that had some precisely defined 'flashing' qualities more in the nature of an artificial beacon. This is clearly the case although the reflecting beacon qualities of the spacecraft are purely a coincidental by-product of its design and serve no useful purpose to the system operators. So what exactly are we seeing and how does it come about. Basically it is not too complicated and can be almost completely understood in terms of simple geometry.

A photograph of the Hughes 376 model shows that its outer surface is covered with nearly 16,000 solar cells. The precise arrangement of these cells gets quite complicated as there are three main regions, several different sizes and also strips of filler cells to maximise coverage of the available surface area. An excellent approximation is that the deploying aft section has 98 cells around its circumference and the fixed forward section 104 (see figure). These values were determined from the FFT before the

Diagram of the Aussat spacecraft with the solar cell skirt deployed This is a standard Hughes HS376 model.



detailed drawings of the solar cell distribution arrived from Hughes. The typical cell size is about 2.3 cm by 6.5 cm with the long axis aligned around the circumference. Since each revolution of the satellite occurs in ~1.08 seconds the reflections from the length wise strips of cells occur at 90 Hz and 95 5 Hz. Both these frequencies together with their harmonics and beat frequencies are clearly present in the FFT spectra.

In actual fact the filler strips on the deploying array are located to give this section a 180 degree symmetry so that the peak at 90 Hz is weaker than the one at 45 Hz. The FFT also shows the fundamental rotation frequency f_0 at ~0.96 Hz, although $2f_0$ tends to have a greater power. Determining the spin frequency enables us to phase fold the data as if the object were a short period X-ray pulsar. A plot of this folded light curve shows many of the individual flashes from the solar cells

The figure produced here is for an integrated nine minute run which represents approximately 480 rotations. Each spike is real and very repeatable since a phase folded light curve for the first minute of data looks almost identical to that for the last minute The apparent brightness of the satellites often seems to be dominated by the beating of the 90 Hz and 95.5 Hz frequencies giving rise to a tendency for roughly six broad peaks of intensity within the rotation light curve. It is this aspect of the modulation which is so visible on the TV screen.

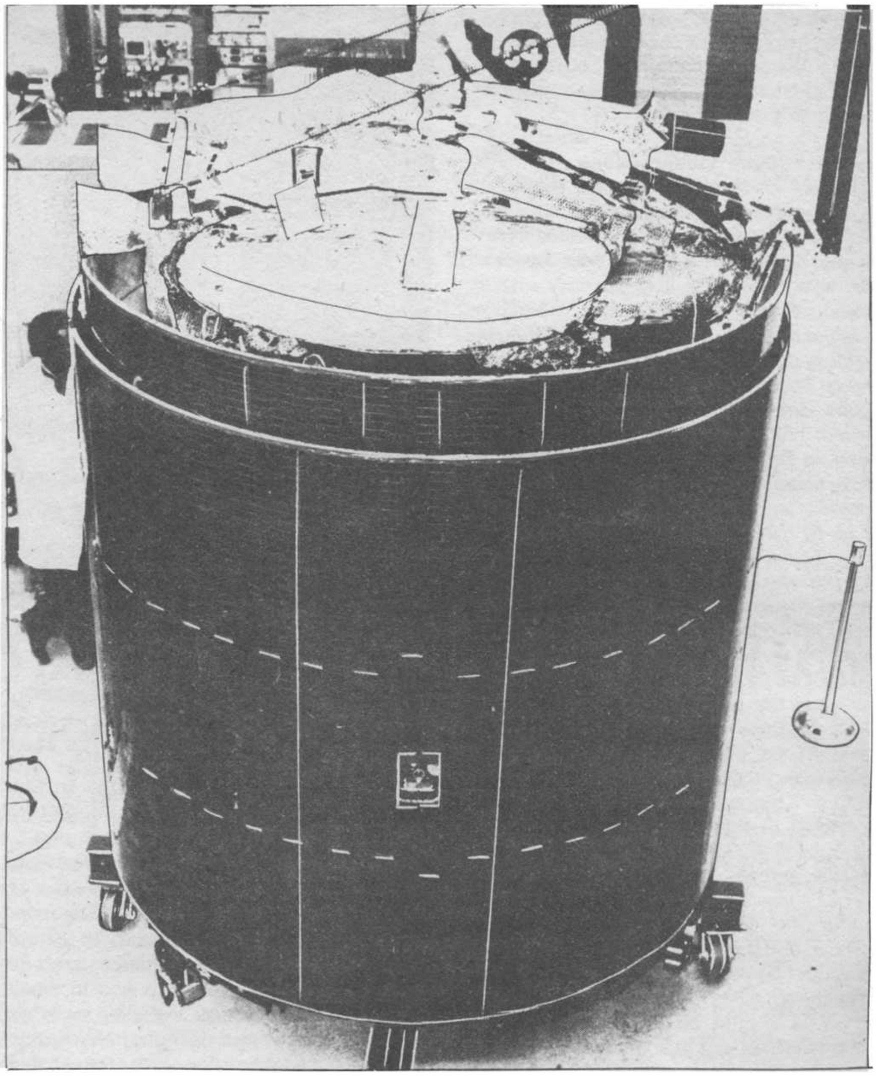
On the outer face of the spacecraft there are also several thousand small thermal radiator mirrors There are 285 of these in a ring around the circumference, and eight rings altogether. The ~266 Hz frequency from these mirrors is also clearly visible in some of the FFT's. The FFT contains a large number of sharp spikes which are also significant in terms of the noise level.

Reflection Geometry

From Hobart at latitude -42.9 degrees, GEO satellites appear north of the Celestial Equator because the satellites unlike the stars, are not at infinity. They all have a declination of about + 6.6 degrees with a relatively small Hour Angle dependence.

Spin stabilised satellites like the Hughes HS376 Aussat units have their spin axis parallel to the Earth, so sunlight incident on the surface at an angle of ~6.6 degrees will be reflected directly towards the latitude of Hobart. The effect here is essentially the same as being in a preferred direction when catching a reflection of the Sun in a distant window. The Sun obviously has a declination of + 6.6 degrees on two occasions during the year and these occurred on April 7 and September 6 in 1987. Quite by chance our first photometry run had occurred very close to one of the optimum reflection dates. We therefore expected to see similar effects around September 6 but were not sure how long the 'on' state would last All we knew was that 18 days past the expected optimum date the satellites were 'off'.

When September approached we attempted to observe Aussat A1 on every occasion but were again frustrated by a run of bad weather. Hobart is not a good photometric site and the weather systems tend to cross the State in four to five day cycles due to our location on the edge of the Roaring Forties. Based on the assumption that the reflected beam might only be a degree or two wide, we did not expect the 'on' state to last more than a couple of days. On September 1, however, the satellites were already 'on' and relatively bright.



A close-up view of the outer surface of Aussat in the un-deployed mode The fixed forward section is just visible at the top of the deploying aft section

We have estimated the brightness on all the nights we observed A1 and plotted them centred about the expected optimum date. The coverage is not very good but the data is well fitted by a gaussian curve centred 0.4 days later than expected. The curve has a half height width of about 4 days. Unfortunately we only obtained a quick look at A1 through a gap in the clouds on September 7 and were not able to get a light curve. We estimate it to have been about magnitude 9 at this time but the proximity of the full Moon prevented us finding A1 with binoculars.

The folded light curves have varied quite a lot from night to night but, as noted earlier, are very repeatable over a period of a few minutes. We have not been able to come up with a definite explanation of these changes or the differences seen between Aussat A1 and A2 on the same night. These two satellites are supposed to be identical. We suspect that all these variations are due to a number of combined effects since the reflected intensity is very sensitive to small changes in the angle of incident sunlight. Regions on the outer surface of the spacecraft may depart from a perfect cylindrical geometry or the forward and aft sections may not be quite optically parallel. Small random orientations of the mirror tiles and solar cells can also be expected, since they are fixed in an adhesive matrix and the exact optical plane of each rectangular piece is unimportant. The two satellites' orbital drift north or south of their mean positions will also be different and they also exhibit a small nutation since the spin axis cannot be aligned perfectly with the Earth's axis and is subject to various perturbing forces. Further observation may identify the exact causes of these changes.

Most sampling of the satellites was done with 1 ms time resolution using a clock system normally synchronised to radio time signals. With a satellite spinning in say 1089 ms and a video display summing every four data samples and displaying 256 points on a screen, a pulse generator strobing the sampling at ~940 Hz produces a real time

phase synchronised rotation light curve. The spin rate can be easily measured by adjusting the pulse generator frequency to prevent features on the screen display marching to the left or right.

Satellite Eclipse Observations

The 'on' mode of the satellites coincides with the eclipse season so care must be taken not to try and find the satellites when near the anti-sun hour angle. With the satellites being stationary it is an easy matter to measure their immersion light curve but the emersion curve is a bit harder as a small correction may be required to the telescope pointing. This can always be estimated if the satellite drift has been monitored for the previous half hour or so. For Hobart the eclipse on September 4 is some way from a central event and lasted about 38 minutes compared to the maximum possible duration of 70 minutes.

The actual eclipse proceeds very rapidly since the angular change in position of the Sun as observed by the spacecraft is the usual Earthbound rate of a solar diameter every two minutes. This interval is lengthened by a factor of ~2 for the example shown here since the position angle of immersion is ~327 degrees. The eclipse immersion of Aussat A1 on September 4, occurred with the Sun's rays passing tangentially through the Earth's upper atmosphere over southern central Russia. The Sun subtends an arc length of ~350 km on the ground as seen from the satellite.

Finding the Satellites

There are two approaches to finding the spacecraft. Since the orbits of these geostationary satellites are always adjusted to stay within a small box centred on the assigned longitude slot this value can be used to compute the local Hour Angle (HA) and Declination. This can be done using a small computer/calculator or by using a diagram such as that given by Taylor in the June 1986 issue of *Sky and Telescope*.

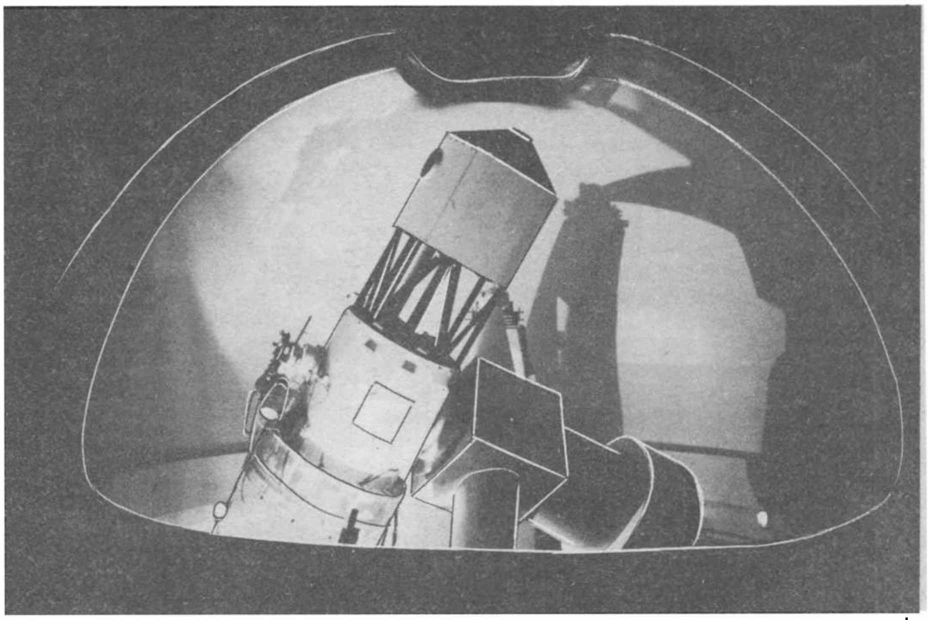
Alternatively the control centre or commercial department of the target satellite can be contacted for the azimuth and elevation which can then be converted to HA and declination. The mean azimuth and elevation are normally provided for the alignment of consumer dish antennae but these angles can be given to better than one minute of arc if accurate values of latitude, longitude and elevation are provided.

It should be borne in mind that the spin rates vary with time but should be within a few RPM of the given value. The exact period is not of importance to the satellite operators and it changes slightly every time a station keeping manoeuvre is performed. These operations tend to normally occur only every few days to conserve fuel supplies.

It is unfortunate that from a given location all satellites are either 'on' or 'off' at the same time. The window of observability of the 'on' state sweeps across the Earth within the period of plus or minus four weeks of the Equinoxes. Simple trigonometry can be used to calculate the apparent declination of a GEO satellite some 36,000 km above the equator and the corresponding optimum dates for the same solar declination obtained from an ephemeris. The trend today is towards three-axis stabilised satellites for communication purposes so the spinning models of today may gradually become rarer over the next 10 years. New model 376 satellites are, however, still being ordered. There are a large number of suitable spacecraft in orbit and we have selected a few in the table below. These are reasonably spaced in longitude and all should be relatively easy to find in small telescopes when in their 'on' state provided there is some way to point the telescope in the calculated direction with reasonable accuracy.

Perhaps these types of object may prove useful as occasional astronomical calibration standards or to measure the Earth's upper atmosphere transmission. The spin rates can be measured to a few parts in a million which should allow perturbing forces to be studied. Long term study may reveal degradation of the solar cells by measuring the reflected solar spectrum.

These satellites will certainly prove useful as practical test objects for student projects since the location and study of such spacecraft provides an excellent introduction to many techniques of current observational astronomy.



The University of Tasmania one metre telescope. This photograph was obtained by taking a time exposure while the dome was rotated.

Acknowledgement

The authors would like to thank Aussat Pty. and Consuo Pty., both of Sydney, for their help and interest. Consuo represent the Hughes Aircraft Company in Australia. Aussat kindly provided permission to reproduce the satellite photograph.

Some Hughes Geostationary Spin Stabilised Satellites operating in orbits as of mid-1987.

Name	HS Type	Launch Date	Life (years)	Longitude	Spin (RPM)
MARISAT 1	356	19/2/76	5	15.0 W	100
LEASAT 1	381	10/11/84	10	15.0 W	30
INTELSAT IVA F4	353	26/5/77	7	21.5 W	55
INTELSAT IV F1	312	22/5/75	7	50.0 W	55
SBTS 1	376	8/2/85	8	65.0 W	55
SBTS 2	376	28/3/86	8	70.0 W	55
GOES 6	371	28/4/83	5	75.0 W	100
TELSTAR 3C	376	30/8/84	10	86.0 W	55
WESTAR III	333	10/8/79	7	91.0 W	100
SBS 4	376	30/8/84	7	91.0 W	55
WESTAR IV	376	25/2/82	10	99.0 W	55
ANIK C1	376	12/4/85	8	107.5 W	55
ANIK D2	376	9/11/84	10	111.5 W	55
MORELOS A	376	17/6/85	9	113.5 W	55
MORELOS B	376	28/11/85	9	116.5 W	55
GALAXY 1	376	28/6.83	9	134.0 W	55
AUSSAT A3	376	16/9/87	10	164.0 E	55
AUSSAT A1	376	27/8/85	7	160.0 E	55
AUSSAT A2	376	26/11/85	7	156.0 E	55
GMS 3A	378	3/8/84	.3-5	140.0 E	100
PALAPA B3	376	20/3/87	8	113.0 E	55
PALAPA B1	376	18/6/83	8	108.0 E	55
MARISAT 2	356	14/10/76	5	72.5 E	100

ISSN 0038-6340

October 1989 US$3.00 £1.25

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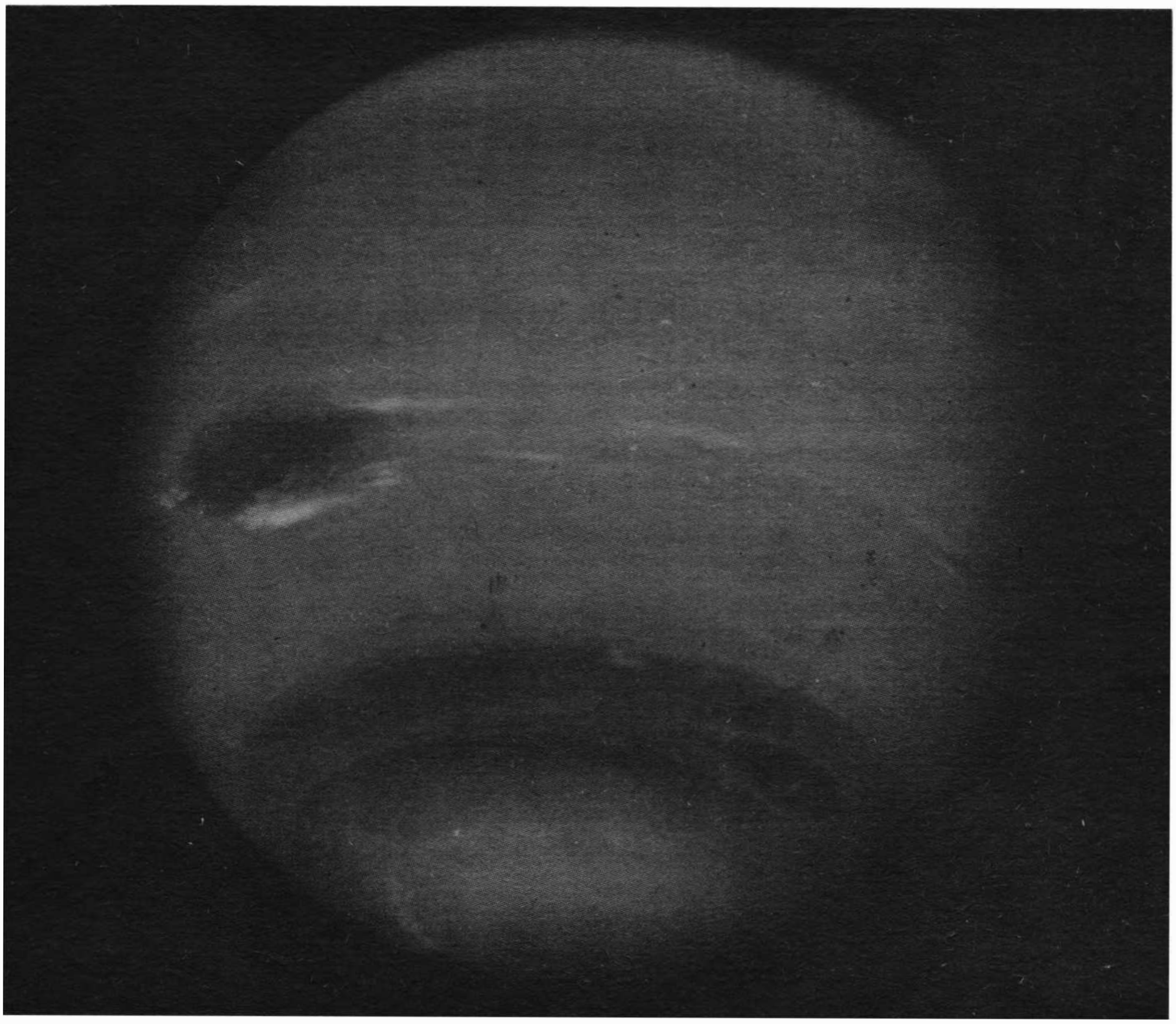

Vol.31
No.10

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Published monthly by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by JWL, Ltd., Aylesbury, Buckinghamshire, England.

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Spaceflight

The International Magazine of Space and Astronautics

Vol. 31 No.10 **October 1989**

Atlantis Set for Jupiter Probe Mission

After Voyager's spectacular encounter with the planet Neptune preparations are nearing completion for the launch of NASA's next interplanetary spacecraft - the Galileo probe to Jupiter. Galileo will be deployed from the Space Shuttle Atlantis during a five day mission due to blast off on October 12. The probe will spend nearly two years investigating Jupiter and its moons. *Spaceflight* previews Atlantis' mission, designated STS-34 and to gain an insight into the deployment of Galileo we interview Milt Heflin, the Lead Flight Director for STS-34.

The Crew

Atlantis will be commanded by Donald Williams, who previously flew in space as the pilot for STS 51-D in April 1985. Pilot for STS-34 is Michael McCulley, a Group 10 astronaut who will be making his first space flight. The three mission specialists for STS-34 includes two women. Shannon Lucid is making her second space flight and at 46 she will remain the oldest woman to have flown in space. Ellen Baker is making her first space flight. She joined NASA in 1984 as a Group 10 astronaut. Franklin Chang-Diaz is making his second Shuttle flight, he had previously flown on STS 61-C in 1986.

This is the first Shuttle mission to carry two women since the Challenger accident.

Launch Preparations

The Space Shuttle Atlantis was returned to the Kennedy Space Center (KSC) from Edwards Air Force Base, after the completion of its mission to deploy the Magellan probe to Venus. The Shuttle was taken to Bay 2 of the Orbiter Processing Facility (OPF) where work began to prepare the orbiter for STS-34. This included servicing the Inertial Upper Stage (IUS) Support Structure that had held the Magellan probe and its IUS booster in the payload bay. The equipment will be reused for the Galileo probe. The orbiter's three main engines were removed for inspection and reinstalled in late June.

In the Vehicle Assembly Building (VAB) work began to assemble the two 47 m Solid Rocket Boosters (SRBs) on June 14. The External Tank (ET) was attached to the two boosters on July 30. Atlantis was rolled over from the OPF to the VAB on August 21 and was mated to the ET/SRBs on August 25. The roll out of the stack was delayed 24 hours by a problem with an ET/orbiter interface. Roll out to pad 39-B occurred in the early hours of August 29. The Galileo probe had been transported to the launch pad on August 25 and was installed in Atlantis' payload bay on August 30.

In early September Pad 39B was evacuated as a safety precaution while engineers installed new seals in the igniters of the two SRBs. Checks revealed the seals had not undergone compression testing at the factory. As a precaution decided NASA to replace them.

Another concern followed a review of the STS-28 launch video. Engineers believed they could see movement in Columbia's body flap located beneath the main engines. Although it is possible the movement was an optical illusion caused by the exhaust from the three main engines, NASA decided to see if there was any free play in Atlantis' body flap. The tests were conducted in the launch pad and there was no evidence to suggest there was a problem. However, Discovery's flap will be examined and engineers plan to replace the actuator for Columbia's body flap.

For safety reasons the two Radioisotope Generators (RTGs), each containing 24 lb of Plutonium 238, will not be fitted to the spacecraft until nine days before launch.

The Galileo descent probe had arrived at KSC on April 17 and was followed by the Galileo orbiter on May 16. The spacecraft underwent final checkout and integration in the SAFE-2 building. The assembled probe was transported to the Vertical Processing Facility (VPF) on August 1 and mated with its IUS booster on August 3.

The final Galileo/IUS preparations were conducted fairly smoothly. However there was one incident on August 15 that gave cause for concern. A faulty compressor at the VPF supplying dry, temperature controlled air to the probe and booster malfunctioned and began sending humid air to the vehicles. Technicians were quickly alerted to the problem but not before condensation had formed on the rocket plume shield of Galileo and on several components of the IUS. It was determined that the condensation on Galileo would have no adverse affects but IUS technicians felt an additional electrical test of the upper stage was required to be sure no damage had been done.

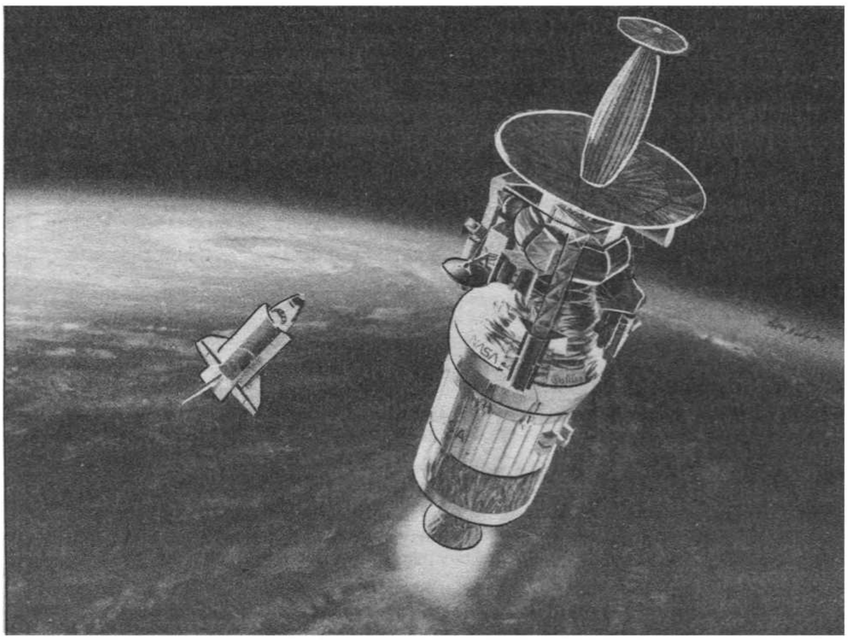
Galileo's move to the pad was delayed by one day due to concerns that a filter in the oxidizer lines for the spacecraft's retropropulsion module could be defective.

The Galileo Mission

The Galileo probe consists of two elements, an orbiter and a atmospheric probe. The orbiter will orbit Jupiter for at least 22 months returning valuable scientific data and high resolution images of the planet and its moons. The atmospheric probe will be released from the orbiter five months before the arrival at Jupiter. As the Galileo orbiter enters Jovian orbit the atmospheric probe will plunge into the atmosphere returning scientific data for about 75 minutes before it is crushed by the immense pressure of Jupiter's atmosphere.

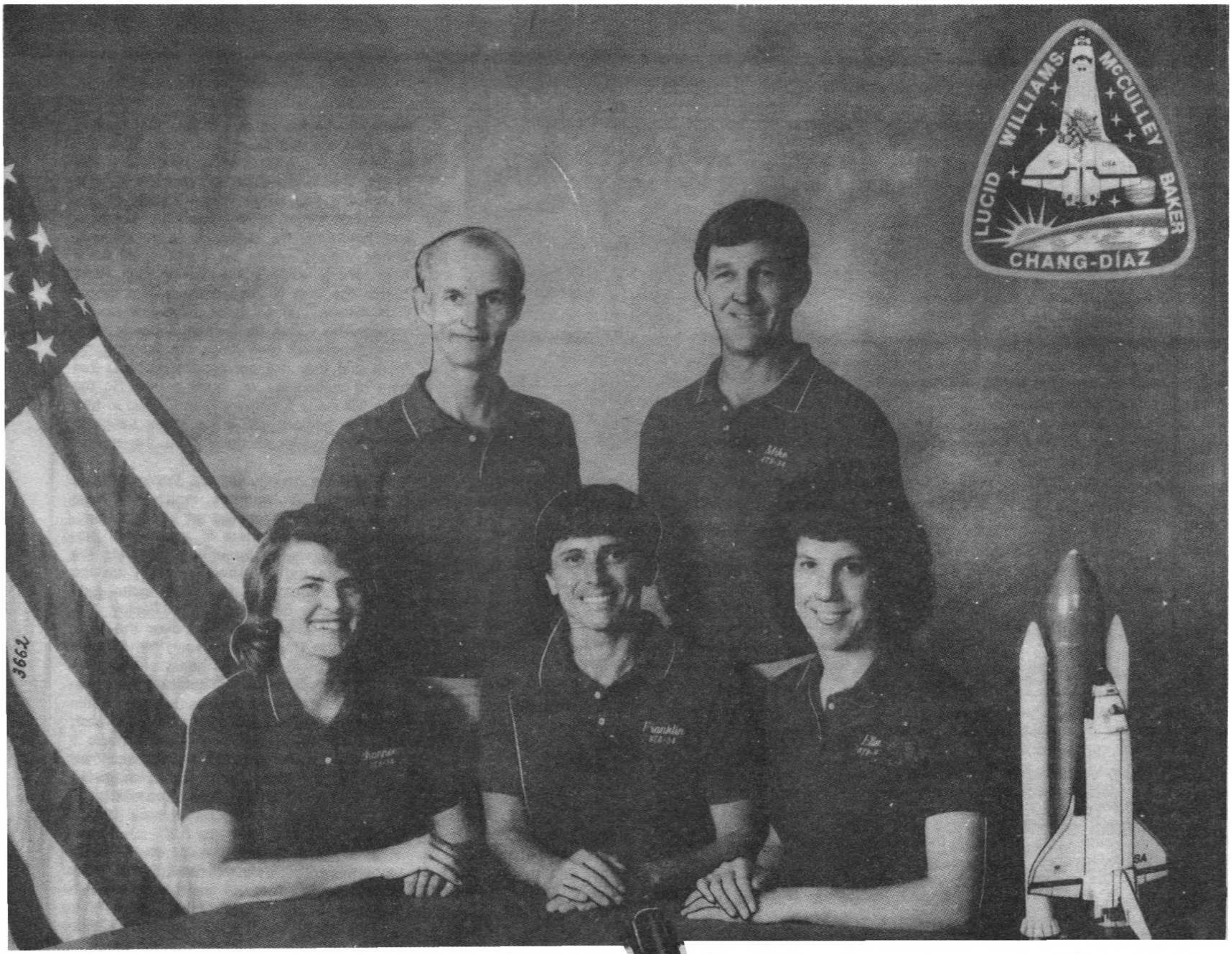
During the early development of the Galileo probe it was planned to use the IUS booster to propel the spacecraft towards Jupiter. However as the Galileo studies progressed it became clear the IUS would be unable to provide enough thrust. One solution was to launch the orbiter and atmospheric probe separately on two IUS boosters. This suggestion was abandoned and it was proposed a powerful cryogenic Centaur upper stage should be used.

An artist's impression of the Galileo deployment *NASA/JPL*



Top: The Galileo crew pose for the traditional crew portrait. From left to right: Shannon Lucid, Donald Williams, Franklin Chang-Diaz, Michael McCulley and Ellen Baker. Their crew patch shows the Galileo spacecraft overlaying the orbiter symbolises the joining together of both manned and unmanned space programmes in order to maximise the capabilities of each. In the distance, Jupiter, a unique world with many unknowns, awaits the arrival of Galileo to help unlock its secrets. *NASA*

Below: The Galileo probe approaches Jupiter, passing close to the planet's volcanic moon, Io. The probe will arrive at Jupiter in December 1995 after a six year round-about voyage. *NASA/JPL*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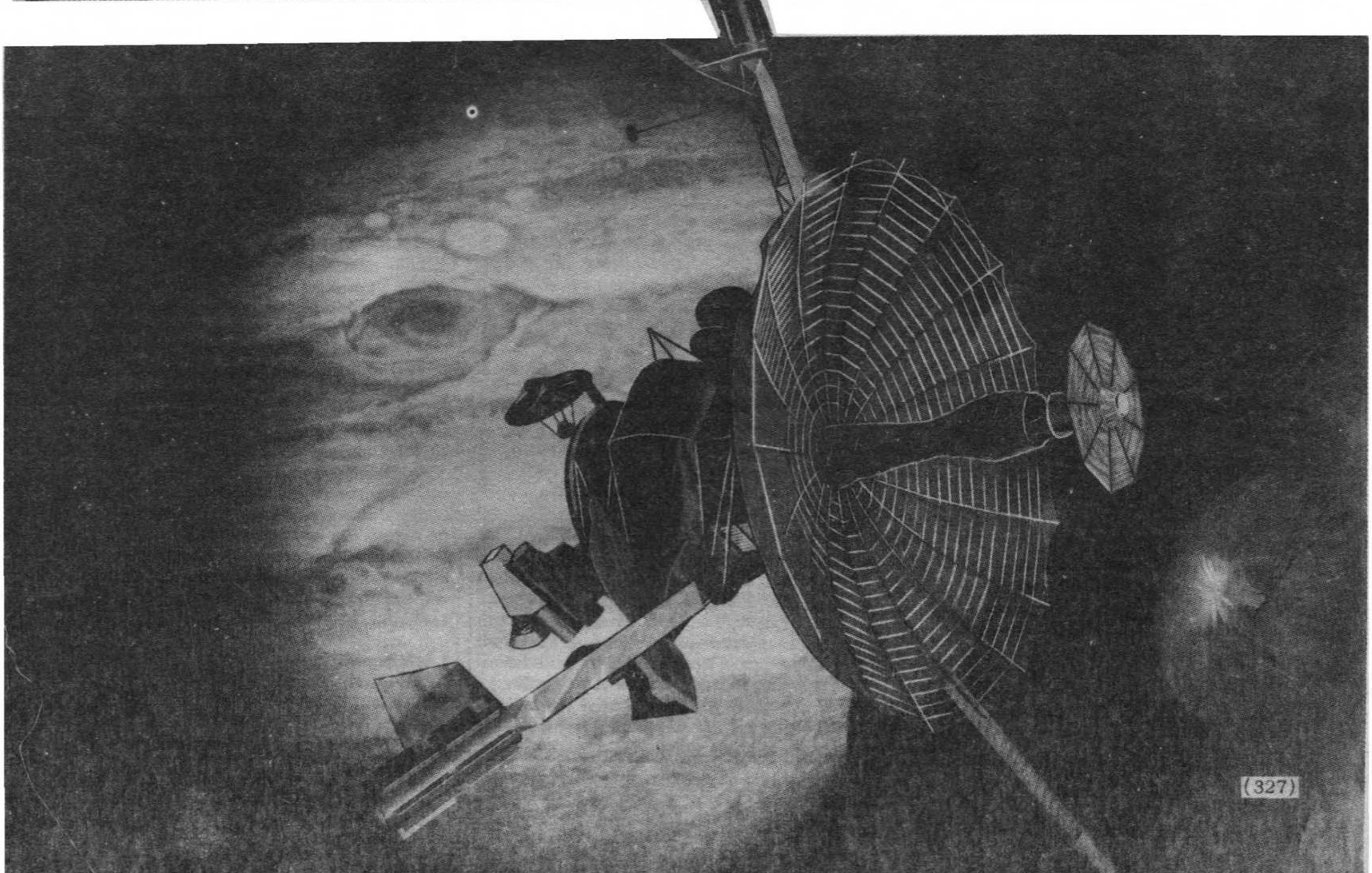
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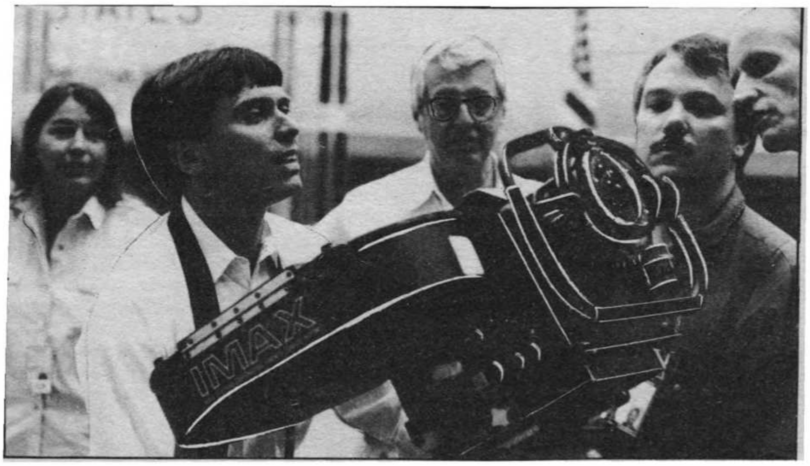


Mission Specialist, Franklin Chang-Diaz, is given instructions on the use of the IMAX camera. *NASA*

Galileo was scheduled for launch on the Shuttle in May 1986 using the Centaur stage. However the Challenger accident in January of 1986 prompted a major rethink of all aspects of Shuttle safety. The Centaur stage became a casualty of the new risk assessments and in mid-1986 NASA announced the cryogenic stage would be replaced by an IUS booster. The problem of mass remained so JPL trajectory engineers came up with a new interplanetary flight path using gravity assists, once with Venus and twice with Earth, to build up the speed to reach Jupitera taking a total of just over six years. This is called the Venus-Earth-Earth-Gravity-Assist or VEEGA trajectory.

If the launch of STS-34 and Galileo goes ahead on October 12, the probe will arrive at Jupiter on December 7, 1995. During its six year round-about voyage to Jupiter the probe will also gather data and images of Venus, the Earth, the Moon and two asteroids, Gaspra and Ida.

Narrow Launch Window

The STS-34 launch window is even shorter than that for the Magellan mission to Venus. The window opens on October 12 at 13:29 EDT for just ten minutes (the Magellan launch had a window of 23 minutes on the first day). The window gradually increases each day until November 2, when it reaches a maximum of 47 minutes. It then decreases through the remainder of the launch period which closes on November 21. If Galileo is to fly-by two asteroids as planned, the Shuttle must lift off by mid-October.

Another consideration is the possible knock-on effect of a delay. The next Shuttle mission, STS-33, is due to blast off on November 19 on a classified DoD mission. Shuttle scheduling is further complicated by the launch of STS-32, scheduled for December 18. Columbia is to recover the Long Duration Exposure Facility (LDEF) which is expected to reenter the Earth's atmosphere as early as January 1990. Any delay to STS-34 could place the recovery of LDEF in jeopardy.

Galileo Deployment

In an exclusive interview, ***Spaceflight*** was briefed on the deployment of the Galileo probe by Milt Heflin, the Lead Flight Director for STS-34, who will be overseeing the deployment from Mission Control in Houston. He described the events leading up to deployment:

"Once we get on-orbit and get the payload bay doors, one of the very first things the crew will do is to issue a command through the IUS to Galileo which will basically start what is called a thermal conditioning of the spacecraft. It has been of course buttoned-up on the pad in a warm climate and once we get on orbit things start to cool down. So the crew will initiate one command to the spacecraft to start some heaters and that sort of thing working. While we are on orbit, until we are ready to deploy, we protect the Galileo spacecraft from direct Sunlight by putting the belly of the orbiter towards the Sun and we hold that attitude as we circle the Earth.

"We then go through a check of the orbiter panels that have the switches and the hardware associated with the check-out and deploy of the IUS. Then we carry out the actual check-out of the IUS hardware. That is done close to about two hours into the flight. Then, through ground tracking, we look very closely at our exact orbit, altitude, inclination, that sort of thing, to get a precise location as to where we are. For about an orbit and a half they will do this tracking and then place that information into a guidance simulator that will do the same sort of thing that the guidance system aboard the IUS does. We crunch the numbers and see if it looks like the state vector we have put on the orbiter and the IUS. The state vector tells the IUS exactly where it is.

"Around five hours and ten minutes into the flight we manoeuvre to what is called the deploy attitude. We have a piece of communications gear on the orbiter that is able to keep the orbiter in contact with the IUS after deploy. We set up the transmitter/receiver so that it is now reading the IUS information directly by RF energy to the orbiter instead of through a hardline.

"We raise the IUS support structure tilt table to 29 degrees about 5 hour and 40 minutes into the flight. Then we begin what we would call a deploy countdown at about 4 hours 50 minutes. Around six hours into the flight we separate the umbilical from the IUS to the orbiter and then raise the tilt table to a full upright position of 58 degrees. Since there is a cooling loop for the RTGs helping to take care of the waste heat, we have a procedure where we will isolate that cooling loop and we can dump the water from the portion of the loop that goes through the RTGs. This is done for two reasons: One is to prevent any water contamination of the spacecraft when those umbilicals separate and secondly to minimise any external forces - there would be some small force from venting water in the cooling loop. Right before the loop is purged there is a procedure where Galileo goes to a low power usage. The RTGs go through a power transient whenever you take the cooling off them and they are not capable right at that time of putting out as much power. So the crew will issue a command to Galileo to turn off some heaters and a few other things to lower the power demand from the spacecraft.

"Then we go into deploy. Deploy time is 6 hours and 21 minutes, which is a time when we typically deploy an IUS type payload. After deploy there is a standard procedure that we go through to separate the orbiter from the IUS and stand by for the solid rocket motor on the IUS to ignite. Ignition will occur 60 minutes after deploy. The deployment will take place over the west coast of the United States and the IUS will ignite over near the east coast of Africa."

If the deployment is delayed there are back-up deployment points as Milt Heflin explains: "We can deploy on the fifth, sixth and seventh orbit and if we didn't make it there we would probably button up over night and we would have opportunities all the way through to orbit 20 on the next day."

Secondary Payloads

After the deployment of the Galileo probe, Atlantis' crew will spend their time tending a number of secondary experiments and taking Earth photographs.

The IMAX large format camera will be carried aboard to record major mission events and the Earth below. Footage from the five day flight will be used in a new IMAX film under preparation. The crew has been given extensive training in the use of the camera which has flown on five previous Shuttle missions.

The Shuttle Solar Backscatter Ultra-Violet Instrument (SSBUV), housed in the payload bay, will be used to measure the ozone characteristics of the atmosphere. The Growth Hormone Concentration and Distribution in Plants (GHDC) experiment will determine the effect of microgravity on growth hormone distribution in various plant life. The Polymer Microgravity Experiment (PM) will determine the effects of weightlessness on morphological formation of polymers as they undergo physical transition. As part of the Mesoscale Lightning Experiment (MLE) the crew will attempt to photograph lightning discharges with still cameras. Their photographs will be supplemented by footage from four colour video cameras in the payload bay. Meteorologists hope the information gathered by this on-going experiment will help predict lightning strikes. AMOS (Air Force Maui Optical Site Calibration Test) experiments will continue. This experiment was described in ***Spaceflight***, May 1989, p.176.

Landing

STS-34 is to conclude with a landing at Edwards Air Force Base in California on October 17.

Twenty-Four Left in British Astronaut Race

From an initial 12,000 phone calls to the Juno 'Astronaut Hotline', the number of candidates was reduced to 35 and now stands at 24. The selection process is now entering a new round of medical examinations which will reduce the number of candidates to about 15.

150 would-be astronauts went through a fitness assessment test at a BUPA Medical Centre in London in early August. The two and a half hour test included electrocardiogram (ECG) and lung function tests while at rest and while exercising on a treadmill. The candidates gave blood samples for the detection of anaemia, early liver, kidney and metabolic disease and measurement of blood fat levels.

Ten women reached the shortlist of 35.

From the results of these tests and a series of interviews, Air-Vice Marshall Peter Howard, the Juno Project's medical director, reduced the number of candidates to 35.

On August 29 the final 35 were gathered together for a briefing on the next phase of medical tests. This is a much more intensive series of examinations including: X-ray tests of the skull, sinus, spine, abdomen and a barium meal and barium enema. Ultrasound scans of the heart, main arteries to the brain, prostrate gland (male) and womb and ovaries (female). Examination of the eyes, teeth, ears, nose and throat, a'nd scope tests of the stomach duodenum and back passage.

The aim of the briefing was to make the Juno candidates fully aware of what they had got themselves into.

On September 13, the number of candidates was once again reduced.

The 24 finalists are aged between 24 and 37 and include four women.

See p.334 for more information on the astronaut candidates.

Hipparcos Marooned in Wrong Orbit

ESA Plans Revised Mission

The Hipparcos satellite is marooned in a highly elliptical orbit after its Apogee Boost Motor repeatedly failed to fire. The satellite was to accurately map the position of stars but will return only a fraction of the information expected if it remains in its current orbit. Scientists hoping to use the Hipparcos data are now calling on ESA to fund a replacement.

Hipparcos and the West German TV-SAT2 were launched by an Ariane 44LP from pad ELA-2 at the Kourou Space Centre on August 8 at 23:25:53 GMT. The Ariane successfully placed the two satellites into a Geostationary Transfer Orbit 35,894 km by 200.5 km inclined 6.89 degrees to the equator.

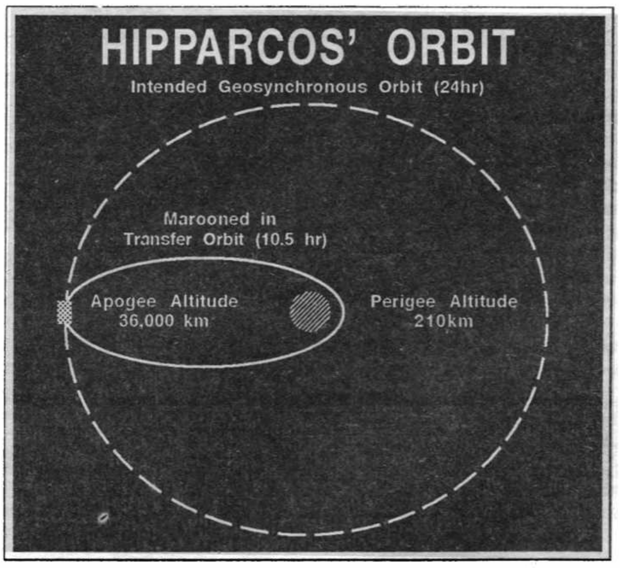
TV-SAT2 fired its Apogee Booster Motor (ABM) about 36 hours 40 minutes after launch to circularise its orbit. However when controllers at the European Space Operations Centre (ESOC), in Darmstadt, West Germany, tried to fire Hipparcos' ABM the motor failed to ignite.

Further attempts were made when the spacecraft reached its apogee on August 11, 13 and 17. However the solid powder MAGE II ABM refused to fire.

ESA has now abandoned all hope of Hipparcos reaching its correct station in geostationary orbit. Project managers have drawn up contingency plans to operate Hipparcos in its highly elliptical orbit. ESOC controllers will use the satellite's five Newton hydrazine thrusters to boost the spacecraft's perigee by several hundred kilometres to about 400-600 km. About 29 kg of hydrazine can be spared for this operation. Before operations can begin Hipparcos' three solar panels must be deployed, as well as the baffles and the antenna.

In its present elliptical orbit Hipparcos will need more ground stations to receive the data. In addition to the Odenwald station in West Germany - which is the primary control station - the ESA station at Perth, West Australia, will be equipped with high speed data links in order to retrieve scientific data. The possibility of using the CNES station at Kourou is being investigated.

ESA is studying methods of modifying the mission planning software which was designed for the intended geostationary orbit. Flight operation plans must be modified, flight procedures must be revised and the complete method of operations must be re-examined.



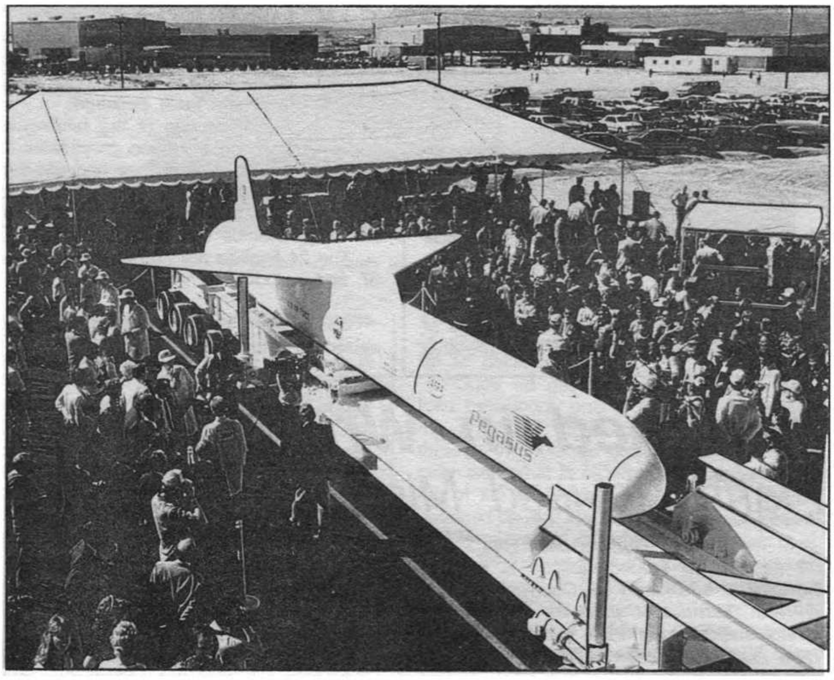
Hipparcos was to have spent its two and a half year lifetime observing 400,000 stars about 80 times to record their exact position and magnitude. The data from Hipparcos was to have been published in two catalogues, which were to become available to the astronomical community in 1993. The Hipparcos Catalogue was to contain the positions of about 100,000 stars to an accuracy of two milli-seconds of arc. The Tycho Catalogue was to have contained some 400,000 stars with a lower accuracy but with detailed two colour photometric information for each star.

The two catalogues can still be produced Dr. Michael Perryman, ESA Project Scientist, told a press conference: "We will still produce a catalogue of 120,000 stars, but with less accuracy. The precision will be a factor of ten less than expected, however, we still hope to achieve a positional accuracy 15 times higher than from the ground."

The amount of data Hipparcos will return will be governed by the effects of radiation on the solar panels. Professor Roger Bonnet, ESA's Head of Science explains: "Every ten hours the satellite goes through the Van Allen Belts and the solar cells get bombarded by protons and electrons in the solar wind 5,000 km above the Equator. Soon we will know more about the possible degradation of the cells on the solar panels, crucial to the length of the mission." It is believed Hipparcos' lifetime could be as short as six months if it remains in its present orbit.

Astronomers hoping to use the Hipparcos data are now calling on ESA for a replacement for the satellite. The cost of constructing a second Hipparcos has been put in the region of £100 million. ESA hopes member nations will contribute the necessary amount or it may have to cut other space science budgets in order to raise the funds.

Pegasus Booster Readied for Launch



The Pegasus Air-Launched Space Booster has been rolled out its hangar before a crowd of 400 onlookers at the NASA Ames/Dryden Flight Research Center, Edwards Air Force Base, California. Pegasus is thefirst all-new unmanned space launch vehicle to be introduced in the United States in 20 years.

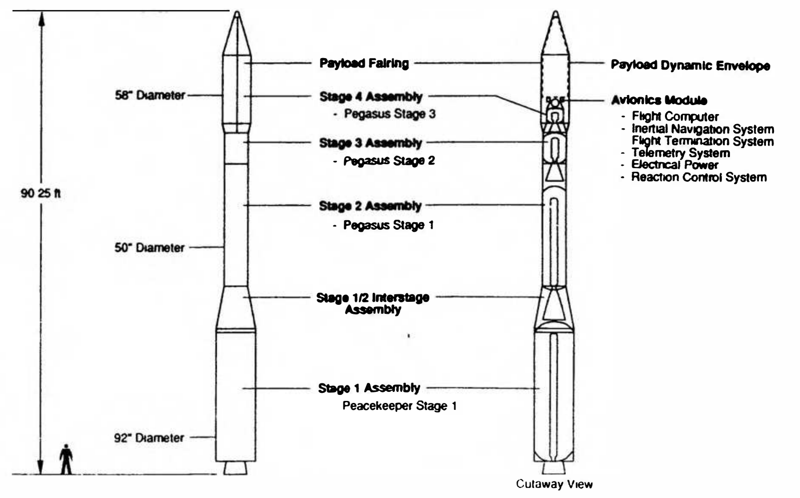
The Pegasus space booster was developed in a privately-financed venture between Orbital Sciences Corporation and Hercules Aerospace Company (for details of the Pegasus vehicle see ***Spaceflight***, March 1989, p.89).

The roll-out marks the completion of a 24 month programme to develop, test and prepare for the first flight of the three stage space booster. Pegasus will now undergo a series of captive airborne tests with its NASA B-52 carrier aircraft in preparation for its first orbital launch, scheduled for late October.

The first Pegasus will launch a NASA/DARPA payload consisting of a military Glomar satellite and a gas release experiment. The Glomar satellite is sponsored by DARPA to help develop a system for both military data relay and an ability for tracking Soviet submarines conceallled beneath the Arctic ice pack. Pegsat, an experiment to release barium gas in space, is being sponsored by NASA's Goddard Space Center. The gas will be released over the Caribbean when observation by radar and optical sensors is possible. The gas released will provide information on the Earth's magnetic field lines. The cost of the mission to NASA is just $1.5-2 million compared with $10 million if the two gas canisters had been launched by Scout.

Pegasus Derived Booster Gets Go-Ahead

Since the loss of Challenger, the US has embarked on a programme of building up a fleet of expendable boosters. The first of these were modified versions of boosters first flown in the 1960s - the Delta II, Atlas II, Titan II and Titan IV. Development of a new generation of launch vehicles was also started - the Pegasus air-launched booster and the Advanced Launch System heavy lift booster. On August 1, 1989, the third member of this new generation was approved. The Defense Advanced Research Projects Agency (DARPA) selected Orbital Sciences Corporation (OSC) to build the new Standard Small Launch Vehicle (SSLV).



The SSLV has four stages. The first stage is based on the Peacekeeper ICBM's first stage. The second, third and fourth stages are from the OSC Pegasus air-launched booster. The guidance system is also from the Pegasus. The SSLV stands 27.51 metres tall and can place more than 1,360 kilograms into low earth orbit and more than 363 kilograms into a geosynchronous transfer orbit.

Up to five orbital launches will be made under the Darpa contract. The first launch is currently planned for 1991 from Vandenberg Air Force Base. The demonstration launches will place experimental satellites into 740 kilometre orbits in support of DARPA's Advanced Space Technology Program.

The SSLV is meant to provide a quick reaction launch system. The booster and launch support equipment can be moved by trucks. An SSLV launch can be made within 72 hours of the order being given. Once operational, the SSLV could be launched from Vandenberg AFB, the Kennedy Space Center and other sites.

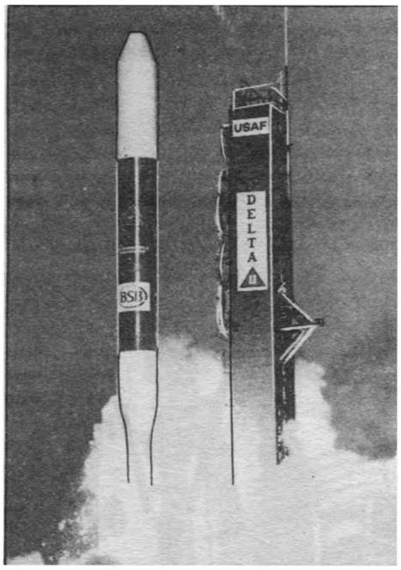
Curtis Peebles

First US Commercial Launch

McDonnell Douglas became the first US company to enter the commercial launch market when it successfully launched a satellite for British Satellite Broadcasting on August 27.

The BSB satellite, named Marcopolo 1 was launched from Pad 17B at Cape Canaveral at 18:59 EDT on August 27. The Delta 4925 vehicle placed the satellite in a 100 x 20,093 nautical mile transfer orbit. The Hughes HS 376 satellite was boosted to geostationary orbit on August 29 when its apogee boost motor was fired. The solar array and antenna were deployed on August 31. Marcopolo 1 will be positioned at 31 degrees west over the UK, where it will transmit up to five television channels to anyone with suitable receiving equipment.

Under BSB's contract, Hughes were responsible for the construction of the satellite, the selection of a launch vehicle and the on-orbit check-out of the spacecraft. This increasingly popular type of agreement means the customer does not pay a penny if their satellite is not successfully placed in orbit.



Insat Accident Report Clears Launch Team

A report on the accident that befell the Insat-1D satellite while sitting atop its Delta launch vehicle says the incident was a 'very random event that cannot be blamed on individuals or procedures.' The satellite's C-Band antenna was destroyed when a launch pad crane hook fell on to it.

The launch of Insat-1D was originally scheduled for launch in July but was indefinitely postponed after the accident which occurred on June 19. The satellite was so badly damaged there were fears it might have to be written off. But after a full examination, Ford Aerospace, the satellite's manufacturers, determined it could be repaired. Insat will now be launched next year.

The report into the accident reveals the crane hook fell on to the satellite when entangled cables sawed across each other, causing one of them to break. The area where the cables were entangled could not be seen by the launch team. There was no load on the hook, which was being lowered in preparation for installing an air conditioning shroud over the satellite.

Meanwhile the Delta first stage intended for the Insat launch was used for the launch of the BSB satellite (see separate item).

Successful Japanese Launch Follows Pad Abort

The Japanese GMS-4 weather satellite was successfully launched from the Tanegashima launch site on September 5. An attempt to launch the satellite failed on August 8 when a problem developed with the H-I booster's first stage.

GMS-4 blasted off from Tanegashima at 19:11 GMT on September 5. Its H-I launch vehicle successfully placed the satellite into a geostationary transfer orbit. The satellite was boosted into geostationary orbit about 16 hours after blast-off. The satellite will be manoeuvred into its position at 150 degrees east.

GMS-4 will be renamed Himawari-4 once it has been declared operational. The satellite will improve meteorological services in Japan and help to develop Japanese weather satellite technology. It will replace the aging Himawari-3 which was launched by an N-II booster in August 1984.

An attempt to launch the satellite on August 8 was aborted on the launch pad. The H-I's first stage engine had ignited and was shut down when computers detected a problem. Engineers later tracked down the problem to a malfunctioning valve in the H-I's vernier engine system.

Soviet Spy Satellite Destroyed

The Soviet Union deliberately destroyed Cosmos 2030, a military reconnaissance satellite, after it went out of control in low Earth orbit.

Cosmos 2030 was launched by a Soyuz booster on July 12 from the Plesetsk. The satellite has been described as a fourth generation reconnaissance spacecraft that normally operates for seven to eight weeks. Reentry vehicles periodically return film to Earth for analysis. During its first two weeks in orbit the satellite seemed to be operating normally but its orbit gradually decayed and attempts to boost its orbit failed.

Soviet ground controllers were obviously concerned the satellite might reenter over a populated area or fall into the hands of Western intelligence. So on July 28 the satellite's onboard explosives were detonated causing the spacecraft to break-up into 50-55 small pieces which soon entered the atmosphere and were burnt up.

NEWS IN BRIEF

Soviet Shuttle Scaled Down

The Soviet Union has officially admitted its Shuttle programme has been 'scaled down as an economy measure'. The next flight of the Soviet Shuttle will take place in 1991. The Shuttle will be unmanned and will dock with the Mir space station. A crew from Mir might transfer to the Shuttle for the landing phase. The first manned flight will be in 1992 with a crew of 3. Initial plans called for ten Shuttle missions before 1997 but the programme will now be limited to just one flight per year. Recent Soviet reports have said their Shuttle is capable of making 12 flights per year.

Mriya An-225 to Launch Spaceplane

Work is underway in the Soviet Union to develop a spaceplane to be air-launched from the An-225 heavy lift transport aircraft, writes *Theo Pirard*. Spaceplanes launched from the An-225 will have small dimensions and will be used for spacecraft inspection. The Soviets have suggested the spaceplane may be developed with international partners. It could be launched from anywhere in the world from an altitude of about eight to ten kilometres. The spaceplane will have a mass of about 200 tonnes and will carry about three to six tonnes of payload to orbits of 200-300 kilometres.

External Tank Contract

Martin Marietta's Manned Space Systems division has received a contract worth $1.8 billion to produce 60 additional Space Shuttle External Tanks. The NASA order is an extension of a previous contract for 59 tanks. Of these 52 have been manufactured to date.

Final Titan 34D Launched

The final Titan 34D launch vehicle blasted off from Cape Canaveral on September 4 carrying a classified payload for the DoD. The launch vehicle will be replaced by the new Titan 4 heavy lift booster.

Rolls-Royce MatEval Wins Ariane 5 Contract

UK based Rolls-Royce MatEval has won an order worth around £750,000 for two fully automatic ultrasonic inspection systems for use in the manufacture of the Ariane 5. The order was placed by a major manufacturer in the Italian aerospace industry engaged on the Ariane 5 project. The first system will be used to inspect the integrity and adhesion of the thermal protection coating which is bonded to the main shell and dome ends of the rocket casing. The second system measures the thickness and integrity of the thermal protection prior to bonding into the main shell. Both systems provide full colour graphic interpretations of the inspection results.

The Soviets Return to Space

New Progress Makes its Debut

Soviet cosmonauts are once again orbiting the Earth aboard the Mir Space Station. The complex had been left unmanned since April as an economy measure. The reactivation of Mir has seen the launch of a new version of the Progress cargo craft. Later this month the first 20 tonne module will be launched and docked with Mir. *Neville Kidger* begins his Mir Mission Report with a look at Mir's record to date.

On May 13, Yuri Semenov, chief designer of manned spacecraft and stations wrote in *Pravda* that, in over three years of work on Mir, some 5,000 sessions of scientific studies had been conducted. These had involved over 60 kinds of research equipment with a total weight of nine tonnes. Of the 1,162 days that the station had been in orbit it had been manned for 880 days.

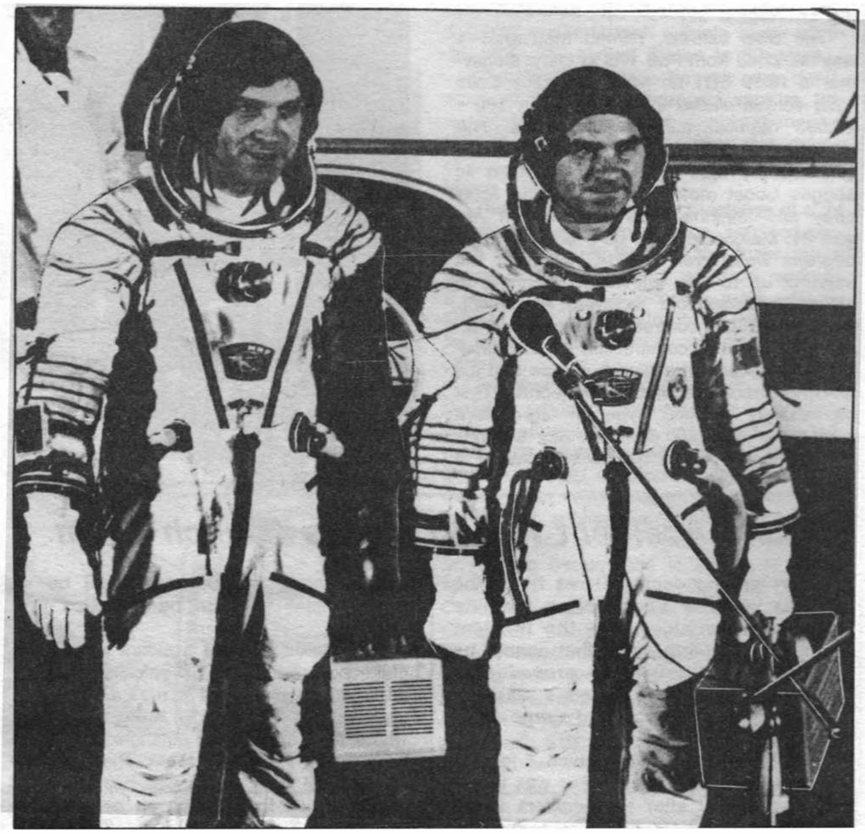
Semenov revealed that the new crew would be launched in second half of 1989 and that testing of a modified Progress cargo spacecraft was scheduled. A research module would be launched in late September and would carry a new videospectral complex which would help create a permanent environmental monitoring service and prevent losses of 1.1 billion roubles per year.

In early 1991 (sic) another module would be launched carrying equipment to work in various bands of the electromagnetic spectrum. The equipment would be used to monitor the disarmament process on Earth, verify agreements prohibiting the emplacement of nuclear weapons in space and thus "promote stronger stability and build world confidence."

At a Moscow news conference on May 23, Glavkosmos chief Aleksandr Dunayev revealed that between the launching of Mir in February 1988 and the return of the Donbas crew on April 27 1989, the development and operational costs of the venture had amounted to 1,471 million roubles. The costs included the launch of the base block of the station, the Kvant astrophysics module, Progress freighters (7-8 per year), the crew delivery vehicles as well as the cost of creating the two new modules and the gamma observatory.

The Soyuz TM-7 Commander, Aleksandr Volkov, told the conference that some 824 communications sessions had been devoted to 64 scientific experiments conducted during the course of the mission. Photographic and spectrographic devices had been used to assess the state of 64 million hectares of arable land in various Soviet republics as well as pollution of the River Volga.

The Mir complex, consisting of the base block and Kvant, continued flying in an automatic mode. Earth-based specialists were using the battery of X-ray telescopes on Kvant to study sources of high energy radiation during the unmanned flight. Equipment for studying the flow of radiation and micrometeorites also operated during this period.



The Soyuz TM-8 crew before boarding their bus to the launch pad: Serebrov (left) and Vitorenko (right). *Novosti.*

Soyuz TM-8 Crews

On July 28 the Soviets announced that the next manned launch to Mir would take place in mid-September and the flight would last for several months. Lt-Gen. Vladimir Shatalov, head of cosmonaut training told reporters at Star Town that two crews were preparing for the launch.

The first crew consisted of Col. Aleksandr Viktorenko, commander, and Aleksandr Serebrov, flight engineer. The second team consisted of Col. Anatoli Solovyov and Aleksandr Balandin. Before the cancellation of the flight when it was scheduled for April 1989 Viktorenko and Balandin had been the prime crew with the two others as their reserves.

The first of the two modules to be launched to Mir would carry the Soviet version of a manned manoeuvring unit which would be tested by Serebrov. The crew would receive two modules with the first being launched in mid-October.

On August 15 it was revealed that the launch was planned for September 6 with launches of modules in October and January-February 1990.

The second module (the "T" or Technology module) would carry a special docking device which would enable the Buran orbiter to be attached to the complex.

On August 22 the Mir complex was in an orbit of 402 x 386 km. It was announced that a new X-ray source had been registered by the Kvant telescopes on August 16. TASS also announced that the next day would see the launch of a Progress-M cargo craft.

Progress-M

In November 1988 Vladimir Shatalov revealed that the Soviets were developing uprated versions of Progress and Soyuz TM. Some Western observers expected that the new version of Progress would be launched from the Baikonur Cosmodrome on the recently declassified "Zenit" booster.

The Progress-M was launched at 0310 GMT on August 23 into an initial 235 x 191 km orbit. The TASS announcement pointedly omitted the identification of the launch vehicle, ***Spaceflight*** understands that there were no orbital fragments - the hallmark of the Zenit booster - associated with the launch of Progress-M.

Later descriptions of the vehicle revealed that it carries solar panels for power generation and a docking system like that of the Soyuz TM. The station's batteries will be recharged from Progress-M's panels. Any surplus fuel aboard the cargo ship, which would normally be lost during reentry, will be piped into the complex.

The cargo bay has been enlarged enabling the craft to carry 2.5 tonnes of cargo to Mir. The Progress-M6 mission will see the addition of a recoverable section which can

return 150 kg to Earth.

It appears Progress-M is unmanned version of the Soyuz TM with an option for exchanging the manned recoverable section with a fuel or cargo compartment.

Progress-M docked with the front axial docking port of Mir, according to Soviet accounts, at 0519 GMT on August 25. The previous Progress version could only dock with the rear docking units of Salyut and Mir.

Soyuz TM-8 Launch

As Progress-M departed the cosmodrome the two TM-8 crews arrived. They stayed at the Kosmonavt Hotel where, as tradition dictates, the flight crew autographed a door before blasting off.

TASS revealed the flight was scheduled to last for six months. It was later announced that the men would return to Earth on February 19, 1990, although no indication was given when or if a new crew would be launched to take over the permanent manning of the complex.

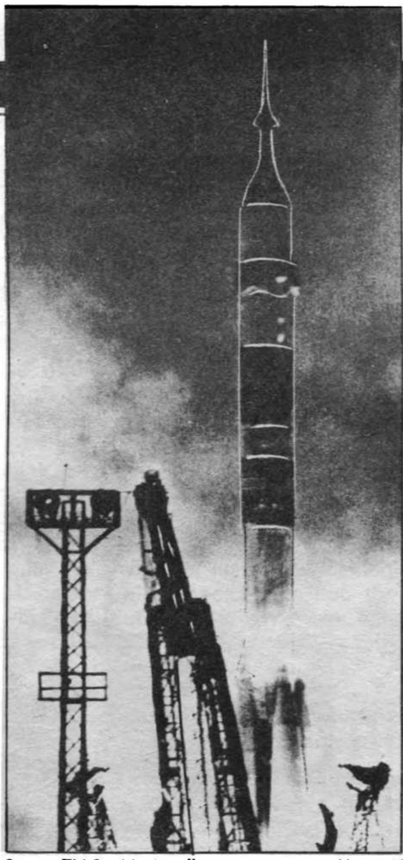
Soyuz TM-8, atop its carrier rocket, was rolled out to the launch pad on September 4 and later the crew for the flight was confirmed as the Viktorenko and Serebrov partnership.

Radio Moscow announced on September 5, that the launch time was scheduled for 2138 GMT (0138 Moscow time, September 6) on that day. An international corps of journalists was at Baikonur to cover the launch.

The Soviet's commercialisation efforts continued during this period with advertising hoardings in the hall where the preflight news conference was held and the by-now familiar launch pad placards also being joined by adverts on the carrier rocket itself.

The launch of Soyuz TM-8 was on time and shortly the two cosmonauts aboard were settling down to the two-day coast to the Mir station.

The Soviets announced that the launches of the two modules would occur about October 15 and January 30, 1990 respectively.



Soyuz-TM-8 blasts off. *Novosti*

Late on September 7 (GMT) the spacecraft made its final, automated approach to Mir. At a distance of just 4 metres from the station there was a problem. The station began to move to the left and also shift upwards and downwards.

Viktorenko took over control of Soyuz and withdrew to a distance of 20 metres. He then initiated a manual approach and successfully docked with the station at 2225 GMT.

The cosmonauts crossed over into the station the next morning.

Radio Moscow said that, as well as receiving the two new modules on their six month mission, Viktorenko and Serebrov would also make five EVAs including tests of the manned manoeuvring unit.

Future Flights

The Glavkosmos agency has concluded a number of deals for future international commercial manned flights to the Mir station. The timetable for these was announced on Radio Moscow on September 5.

The first two, those with representatives of Britain and Austria*, would take place in 1991. The following year would see missions with representatives of West Germany, France and Spain. The inclusion of the Spanish flight took most observers by surprise. A formal announcement of the deal is awaited.

Missing from the list announced on September 5 is the flight of a Japanese journalist. There was no explanation given for this omission. On August 17 TASS reported that the Japanese TV station TBS had shortlisted five men and two women from its squad of journalists.

However, in July the journal *New Scientist* had claimed that of the seven candidates shortlisted from 98 applicants, three of them had been rejected by Japanese doctors and visiting Soviet specialists had rejected the other four. The doctors said that two of the applicants might be acceptable after surgery!

TBS, according to *New Scientist* was appealing for "healthy" individuals to volunteer for the flight.

* In our earlier report of the Austrian flight, ***Spaceflight*** August 1989, p.256, it was stated that pilots were to be excluded from the selection. This is incorrect and results from a translation error Johannes M. Fritzer notes that the Austrian selection committee determined that the applicants *need not* be fighter pilot status

Glasnost and the Moon

Recent revelations in a Soviet book and newspapers have confirmed that western observers thought and the Soviets denied - that the USSR was actively planning to fly men to the Moon in the late 1960s and early 1970s.

In addition to the revelations in the book *Cosmonaut Number 5*, which were reported in ***Spaceflight***, September p.293, the newspaper *Izvestiya* has carried an article detailing the history of the Soviet moon programme.

In 1960 a Soviet government decision called for development of a lunar booster to be called N-1. It would have a payload of 40 to 50 tonnes and would fly by 1964. However, the project was reviewed almost every year until, in November 1966, an expert commission approved the plans for a lunar mission using a booster capable of lifting 95 tonnes.

The newspaper details disagreements between the legendary chief designer, Sergei Korolev and Valentin Glushko, the chief designer of rocket motors.

Korolev wanted N-1 to have engines burning oxygen and hydrogen but Glushko believed that fluorine, nitric acid, dimethylhydrazine and other extremely toxic chemicals would make better fuel components.

Respective motors were eventually devised and four trial launches were conducted. These were:

- February 21 1969: This flight ended after 70 seconds when a fire developed in the tail section of the rocket.
- July 3 1969 (*Izvestiya* gives the date as 1970 but this is incorrect): An oxygen pump failure caused a powerful explosion wrecking the launch site and causing a fire so intense that it was registered by American satellites and reported in the magazine Aviation Week and Space Technology.
- July 21 1971 (this date is probably also wrong, with June being more likely correct): On this occasion the rocket fell back to the launch pad and caused yet more extensive damage.
- November 23 1972: After 107 seconds of flight the rocket developed a fire in its tail section.

There are, as yet, no official accounts of casualties associated with these failed launches.

The lunar plans called for a two man mission, with one cosmonaut landing on the surface of the Moon and the other remaining in lunar orbit.

However, it was a surprise to everybody on the project when work on the N-1 was at first frozen and then abandoned altogether following the replacement of the successor to Korolev, Vasili Mishin, by Glushko.

Glushko suggested a new concept which led to the Buran orbiter and the Energia booster which has practically the same thrust as the rejected N-1.

Izvestiya commented that the fate of the aborted lunar expedition and the N-1 reflected the painful problems of the entire Soviet society, including excessive politicization of science, the substitution of sham goals for worthy ones, voluntarism, and lack of collective decision-making on crucial issues. The newspaper also said that the "unwarranted" race with the USA to land a man on the Moon also contributed to unsteadying the Soviet effort.

Neville Kidger

The 35 Juno candidates assemble in London for a briefing on the next stage of the selection process. By September 13, the number of candidates was reduced to 24.
Steven Young

The 24 Juno Candidates

Diljeet Athwal, aged 27, single, from Camberwell, London; a research scientist at Celltech Ltd.

Gordon Brooks, aged 32, married with four children; a Royal Navy medical/research officer.

Karen Carr, aged 31, single, from Clifton, Bristol; a principle scientist at Sowerby Research Centre, British Aerospace.

Patrick Collins, aged 37, single, from Kennington, London; Director of Undergraduate Studies at Imperial College.

William Curtis, aged 28, single, from Abingdon, Oxfordshire; a technology officer at the Science and Engineering Research Council's Rutherford Appleton Laboratory.

Andrew Dennis, aged 29, single, from Redhill, Surrey; senior research scientist at Phillips Research Laboratories.

Robert Eden, aged 31, married, from Warrington, Cheshire; associate consultant at Corrosion and Protection Centre Industrial Services.

Rupert England, aged 30, single, from Bristol; research psychologist at British Aerospace.

David Eyley, aged 29, married with one child, from Paignton, Devon; a senior production engineer at STC optical services division. A Member of the British Interplanetary Society (BIS).

William Greer, aged 26, single, from Swaythling, Southampton; a PhD research student at the department of aeronautics and astronautics at the University of Southampton. A Fellow of the BIS.

Adrian Jackson, aged 29, single, from Putney, London; an equity negotiator/reservoir engineer for Shell Expro.

Alyson Jackson, aged 34, married, from Bishops Stortford, Hertfordshire; a research specialist at Minnesota 3M Research Ltd.

Alistair Kean, aged 28, single, from Glasgow; a research fellow in the department of electronics and electrical engineering at the University of Glasgow.

George Loizou, aged 30, married with 2 children, from Guildford, Surrey; a postdoctoral research officer in the department of biochemistry at the University of Surrey.

Timothy Mace, aged 33, single, from Weyhill, Hants; major in charge of aircraft captain training, army air corps.

Grant Mason, aged 33, single, from Berwick-upon-Tween; currently living in Stockholm.

David Owens, aged 25, married, from Windsor; a pilot with British Midland Airways.

Mary Roberts, aged 25, single, from Harrow, Middlesex; PhD student at the Medical Research Council.

Helen Sharman, aged 26, single, from Surbiton, Surrey; a research technologist with Mars Confectionery.

Clive Smith, aged 26, single, from Hatfield Peverel, Essex; a lecturer in the school of mechanical, aeronautical and manufacturing engineering at Kingston Polytechnic.

Stuart Smith, aged 36, single, from Reading; senior design engineer and head of research and development at Racom Ltd.

Richard Stone, aged 24, single, from Cyncoed, Cardiff; pre-registration house officer in cardiology at the University Hospital of Wales, Cardiff.

Roger Turner, aged 35, married with one child, from Cardross, Dunbartonshire; a senior engineer with the Royal Navy.

Christopher Welch, aged 29, married, from Weybridge, Surrey; lecturer in space technology at Kingston Polytechnic. A Fellow of the British Interplanetary Society.

Experiments for Juno

THE primary goal of the Anglo-Soviet Juno mission is to conduct a series of experiments proposed by the British scientific community in microgravity conditions aboard the Mir space station. Professor Heinz Wolff of Brunei University has been charged with the task of organising the selection of the experiments that will actually fly. In an exclusive interview with *Spaceflight* Professor Wolff discusses the selection process.

How did you become involved in the Juno project?

Well I have been involved with ESA since 1975. I was helping to set up what was then the life science working group when ESA suddenly discovered they had a Spacelab and no experiments to put in it. The Royal Society nominated me to be one of a small number of people to set up this group. Ever since then I have sat on committees, or more usually chaired committees, within ESA which were concerned with a microgravity programme. So when Juno came up I was relatively well known and also I made myself politically more visual in terms of rooting for Britain to play a more prominent role in space. I suppose I was a fairly obvious choice - that's not a question of my own personal merit, it is the fact there are so few people in this country who are involved in it.

How did you go about bringing the mission to the attention of industry and the scientific community?

Well curiously enough I didn't! The usual way, had we had a lot of time, would be to do it the way of NASA and ESA - you would publish an announcement of opportunity which would describe the mission and the kinds of experiments that were possible. We would then have given people several months to make proposals and send them in to us and then there would have been a process of weeding them out. Now because we were late in starting the mission we could not do that, we simply didn't have the time. So what I did was to obtain from ESA the names of all British scientists or companies who had ever proposed any experiments for an ESA flight. This gave me a base. Also I know pretty well all the people in this country who have an interest in microgravity. What we could not afford was for people to sit down and say what sort of thing we might actually fly and then perhaps have to do a lot of laboratory work to find out whether it was possible. We had quite a few people who already had an experiment in mind and who might be relatively quick off the mark.

As it happens we have got far more proposals than we can fly, about 60. I think we have had more experiments submitted to us by this totally informal, almost secretive, way of going about it, from the UK, alone than ESA normally gets with the full announcement of opportunity mechanism for the whole of Europe. So any claim that there is no interest in microgravity work is quite fallacious.

Have you been astounded by the number of potential experiments?

I would not say I was astounded. I knew there were a lot of experiments about. We had of course one natural advantage - in the past if you submitted experiments to ESA you knew that even if ESA selected them, you would still have to go cap in hand to some national funding body in order to get the funds to physically build the experiment and to meet whatever other costs were involved. I was able to show that the funds that I had available would be sufficient to build the hardware. The cost of the actual mission would be paid by Juno, moreover I would be able to pay the travelling costs to and from the Soviet Union, the expenses in that country and perhaps make a modest contribution to the consumables and other costs that experimenters may have in their own laboratories, but what I could not do was to actually pay the salaries of the people working on the experiments.

"We have got far more proposals than we can fly, about 60."

What I was able to offer was so much more than anything that had ever been offered from the British funding authorities with very few exceptions and this itself I am sure played a part in stimulating people to come forward. People had learned over the last 20 years that it was almost hopeless to propose an experiment because so very few of them ever got funded.

So this is the best opportunity ever for British scientists interested in microgravity experiments?

I have no doubt whatsoever.

What are the basic requirements for an experiment, because obviously there are certain restrictions?

We did not know exactly what these restrictions were until quite recently. We have had a Glavkosmos deputation over here of six people: two of them were engineers, two were concerned with the medical programme and two were business men. After almost ceaseless meetings we have now elicited a good deal of background information. There is a party of us going to the Soviet Union in September to have a second bite of this and to actually propose a payload to them.

Now the constraints are basically that we have 100 kg of payload but, if the experiments warrant it, we can go up to 300 kg, by buying ourselves extra payload. What surprised us, what we did not know when we actually planned this, was that we, perhaps naively, thought that our astronaut would be able to take our experiments together with him as hand luggage as it were on the Soyuz TM spacecraft which would carry him to Mir. We discovered in the course of the interviews which took place with the delegation that the astronaut would only be able to take 20 kg with him, including his personal effects. We will now have to freight the main part of the experiments, actual hardware, on a Progress unmanned cargo freighter to Mir about three months in advance where, the crew that is onboard Mir will unload and stow it. All our astronaut will take with him will be the sensitive parts, particularly the biological experiments - the egg, the protein solution or whatever - in a special refrigerated container which we will have to design and build and he will then, once he gets there, have to insert the preparation into the experiment.

What is even more constraining is that on the way back you are only allowed 10 kg and this will have to include any non-perishable things. For instance if the astronaut has made some interesting new alloys, then this will have to be part of the 10 kg. So there are some problems about what we can return and of course what we will try to do is to return as much information as we can on tape, in pictures on film or even to transmit the information back to the ground so as to reduce to a minimum the amount of return payload we must have. The last word has not been said on this. We found our Russian partners understanding. I think they behaved extremely cor-

rectly by saying to us what we can guarantee you now are those 20 kg going up 10 kg going down. But of course as the mission develops and we have more idea what the Russian national programme is going to send maybe some of these things can be relaxed slightly. So we have mass and volume problems. Now when we get on to the spacecraft I think there are no particular constraints. The constraints are really of our own making, in that we have so little time that the complexity of the machinery that we can actually construct in just about a year (until we have to deliver) is itself limited. In fact there are people - the professionals if you like - who would say it cannot be done, that to produce flight hardware, which is flight qualified, in a year has never been done before and it is really very difficult. It seems likely - although it is not certain at the moment - that industry will help us in the flight qualification trials and what perhaps is more important, to advise us on short cuts in design.

I am convinced, having had a little experience in designing these things for ESA, that we do have some tricks up our sleeves, particularly in terms of miniaturisation and making things really rather small and by using a great deal of commercial equipment which already exists, that we will be able to meet our deadline. So complexity and size of the equipment is one of the constraints. Another constraint is that people are only now giving us proposals that require some preparatory work on the ground and that too could ultimately be a constraint. And lastly I suppose there is how much money I have got.

I find myself, together with my technical and scientific colleagues in an interesting position where there is a constraint at one end of mass, you must not have more than so many kilograms. On the other hand there is the distribution of the mass, 20 kg up, 10 kg down. There is a financial envelope, I cannot spend more than a certain amount of money. There is a time envelope, what can we actually make or get made in that time. There is an envelope of having to satisfy the requirements of the Russians, in terms of documentation in advance, safety reviews and things of this type. All this takes time and mountains of paper work is produced.

There is one more area, that is crew time. We could have experiments which fit into the payload but then everybody wants everything done on Thursday afternoon and it may simply not be possible for our astronaut to accomplish all the experiments. We will have to produce a timeline for the astronaut: what he actually does every minute of the day, bearing in mind he will also have certain duties to our sponsors who are paying for the mission. So I do not know which of these buffers I am going to run into but I will know within the next six weeks or so when we will have a much clearer idea of what the payload is. It will not be until we submit our plans to the Soviet people in the middle of September that we will have gone fairly firm. By the end of October we are under obligation to give them a lot of information about what the payload actually looks like so they can make accommodation studies, power studies and work out where to stow the stuff on the Progress spacecraft. So we are going to have our work cut out.

Have you any idea how much time will be available for work on the scientific programme?

Well our astronaut will have roughly speaking 48 working hours. The way the crew is organised is that they all sleep and eat together, so notionally there is an eight hour working day. Now some of the astronauts will have other things to do, they may have national things to do for the Russian programme and also I think two of them - although I do not know this for certain - are to return to Earth quite soon, either with our astronaut or soon after and asthey will have been there sometime, so they have an exercise programme to recondition them for their return to Earth. That exercise programme is a little bit of a nuisance to us because it degrades the microgravity environment, which has been quoted to us that as normally being better than 10^{-3} g and probably nearer to 10^{-4} g. But when the astronauts are exercising, generally rattling around inside the spacecraft, it could go down to 10^{-2} g. We have discussed this with our Soviet colleagues and they have suggested that experiments which, at least in the starting stages, are likely to be very g sensitive, for instance some of the crystallisation studies might be started during the night. So it could be that our astronaut may be doing some things outside of his normal working hours - he would be doing overtime! Another interesting thing we discovered was that the atmosphere in Mir is really rather variable. Not only is it variable in atmospheric pressure, between about 450-970 mm Hg, but also in its composition it can be up to 3% carbon dioxide and 2% hydrogen. This means our experiments will have to have their own private atmospheres which we will have to stabilise in terms of pressure and composition because otherwise we could never say when we come back whether some extraordinary effect that we might have observed was due to some impurity or some condition of the atmosphere or the sudden pressure change rather than a microgravity effect.

What is the process for selecting the experiments?

I have asked people to serve on a peer group who are well known scientists in their own right and who are not themselves concerned with flying experiments, although that in itself has not been ruled out. They are people the scientific community would recognise as being reliable and people with a good deal of judgement. We will submit all the experiments to them and get them to pass a judgement as to whether they are worthwhile from a scientific point of view. However that is only one of the conditions the experiment has to meet: it might be very worthwhile but it might weigh 500 kg and we could not fly it. So this information will be taken in conjunction with a study of technical feasibility. In fact when we submit a proposal to the peer group we will give them some idea how feasible or otherwise we believe it is and also whether we believe it is going to pose any safety hazard. I have had one meeting with them already and they seem entirely reasonable people. They have had some association with me by serving on ESA committees so they know what it is all about. They will have a certain youngness of heart which of course prominent scientists often have because they are inquisitive like young people so I think they have entered into the spirit of this. I think we will get a great deal of help from them. We have another meeting on September 4, when at least as far as the biological experiments are concerned we will arrive at a short list, with perhaps slightly more experiments than we can actually fly. But the way it may turn out is that many of the experiments will require very similar facilities. For instance a particularly standard kind of thing will be an incubator, which will simply be a container which allows us to control the temperature, pressure and gas inside, with one or more little centrifuges inside it because whereever possible we are going to run a one g control centrifuge so when we come back we can say this happened in zero g and this happened in one g and we are going to have the experiments done on the ground as well. So we do have a pretty high level of assurance that whatever effects we observe are due to the microgravity effects and not due to some other effect like cosmic rays or heavy particles or whatever. This incubator with centrifuges in it may be a pretty common thing for the biological experiments which involve

tiny plants, cells, eggs and so on. So it may be that we fly a limited number of facilities but these could contain perhaps quite a large number of experiments because there is no reason, if the temperatures are compatible, that the incubator - which will actually turn out to be a large stainless steel thermos - should not have an egg experiment at the top, slightly lower down a cell experiment and then lower still a plant experiment, all in the same incubator. I am fairly bullish at the moment so far as the number of scientists we could involve.

Once the British side has selected its choice of experiments will the Soviets make a final decision whether the experiment goes ahead?

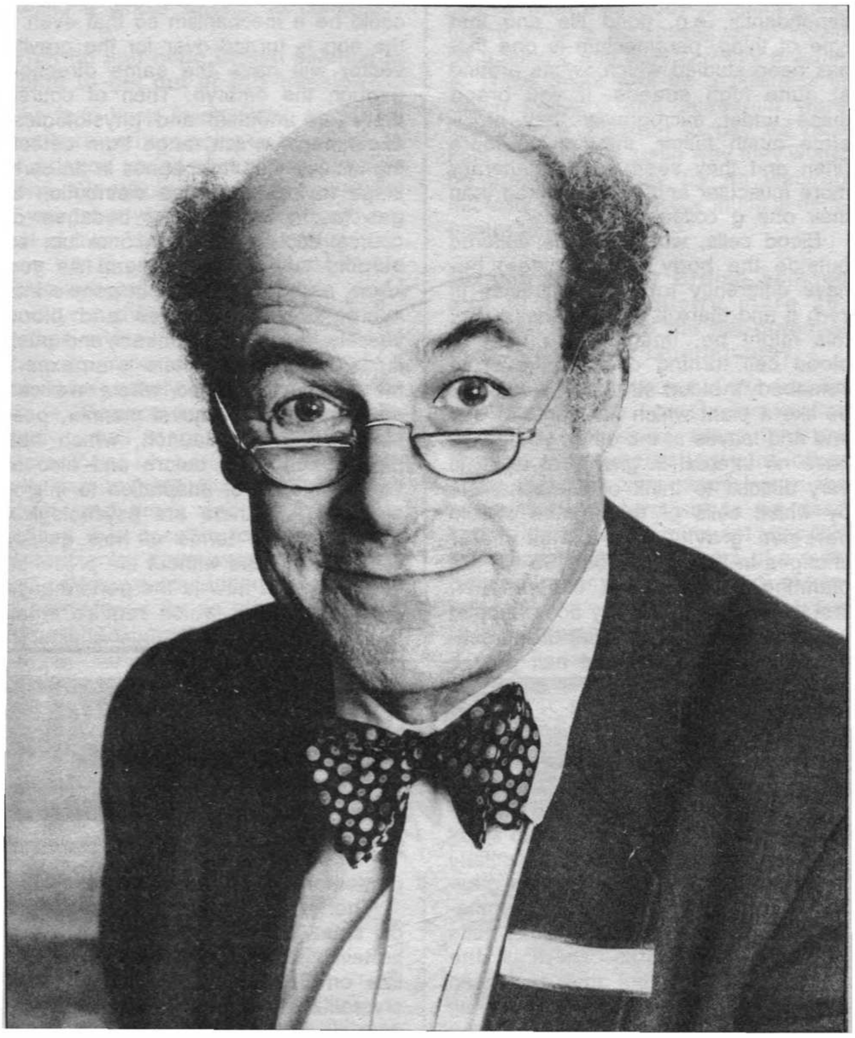
Well I asked exactly this question because I would have been mildly miffed if having submitted the British experiments to a really rather high powered peer group they would have then had to run the gauntlet of another group of scientists about whom we know really rather little. As far as I can make out the review on the Soviet side is going to be on the basis of safety or technical feasibility, not on the basis of whether the science worth doing. So we would have to get it past our Soviet colleagues but on technical grounds.

Will you be preparing back-up experiments?

I think we will have to do that. I do not quite know what the reaction would be in terms of accommodation. I think if we wanted to do that we would have to make sure that the volume and mass of the substitute experiment was close to the other one because otherwise it would disturb any studies the Soviets had made. This question of mass seems to be particularly critical on the reentry stage, when we have ten kilograms. The capsule has a centre of gravity adjusted very carefully even to the point of ballasting the chairs in which the astronauts sit to a constant weight so that the little jets that present the heat shield to the atmosphere can work properly. I think the reason they are so tight about the return payload is that the centre of gravity of the capsule is pretty critical.

It has been mentioned that schools would be able to submit experiments. Have any been put forward?

Well we have got one or two submissions from schools and we would like some more. I went to the Space School in Sevenoaks and on the last evening I happened to get hold of one Juno T-shirt and I had a sort of impromptu instant prize giving where I got the audience to suggest experiments to



Professor Heinz Wolff. *Granard Rowland*

me and whoever suggested the best experiment would get the T-shirt. I got a surprising number of experiments and one of them seems to be a perfectly sensible experiment to do. The Hydra which is a little pond life form which is a multi-cellular creature. It is in fact quite a complicated creature with the capability, like many primitive organisms, that if you snip a bit of it off not only does it grow a new bit but the snipped off part can grow a complete new organism for itself. I had previously lectured that we do not know in developmental biology if gravity is used as a plumb-line that an organism uses as a scaffolding to organise itself against. So it seemed perfectly sensible to ask whether the hydra would be able to do this. Snip a little bit off and see if it grows a new hydra. What I have not discovered is whether we have enough time,as I do not know how long it takes to do this. Maybe we would have to use some kind of tropical hydra which very likely grows faster. It is really questions of this kind - I wonder what? - that schools should be encouraged to ask.

The other kind of educational experiment is one where it is not as much a question of asking a question and making a discovery, but demonstrating some physical principle in a way which is difficult to demonstrate on Earth. Things to do with surface tension where liquids will climb up the side of a glass and may be climb over the other side of it if it is wettable. Or I have a sort of desire, but I do not know if it is possible, that one might create a mini-solar system by having tennis and ping-pong balls with electric charges between them orbiting around one another.

Can you give a brief outline of the type of experiments that have been suggested?

I will have to do this in terms of kinds of experiments rather than individual experiments. Starting with the biological side at the lowest form of life - singular cells. On previous flights it has been shown that among cells which live in-

dependently, e.g. pond life and that type of thing, paramecium is one that has been studied which swims around at quite high speeds. If you breed these under microgravity they proliferate much faster, they divide more often and they seem to be generally more muscular and rosy cheeked than their one g colleagues.

Blood cells, which can be cultured outside the body (lymphocytes) behave differently towards antibodies in zero g and there is no hypothesis why this might be. Imagine you were a blood cell turning over and over in somebody's blood stream, it would not be like a plant which has roots at one end and leaves at the other, you would have no interest in gravity at all. It is very difficult to think of a mechanism by which cells of that nature should perceive gravity and exhibit major changes in their behaviour. So we are planning a number of experiments, first to prove this actually does happen and to try to measure what the threshold is: does it happen at half g or a thousandth of a g? Now this is so fundamental to how cells work that I personally believe that these will be some of the more important experiments which we might do.

Then going up in state of organisation there are people who want to study plants in various ways and particularly the way in which plants perceive gravity. They have a special accelerometer inside them and people do not quite know how this works. There is one quite nice experiment that has been proposed that will once and for all answer the question precisely how this thing works. Then there are the physiologists, biologists who are concerned with development of animals from single cell egg to complete organism. It has often been suggested that gravity plays some part in this, particularly in the early stages and it would be very unusual if economic nature, which tries to use everything, should not use gravity as a sort of plumb-line.

There are experiments at the worm level, rather primitive things. There will be experiments perhaps at the reptile level and there will be experiments at the bird level (warm blooded) which will study if an organism in the early stages of development, when the front and back are determined or when the outlines of the skeleton are laid down, whether without gravity this happens. It is known in a rather anecdotal way that if you disturb eggs, particularly of reptiles, by turning them over that the embryos develop abnormally. If you have ever eaten a boiled egg, which I am sure you must have done, you will see the egg goes to some pains to suspend the yolk on strings at either end so as to keep the fertile bit of the egg upwards. This could be a mechanism so that even if the egg is turned over for the gravity vector will have the same direction through the embryo. Then of course there are medical and physiological experiments which range from detecting mineral loss from bones in an early stage to looking at the distribution of gas in the gastro-tract because of course bubbles do not come up, so burping is quite a problem! As you know, as soon as you put people into microgravity the tissues and blood vessels in the legs contract and push fluids up the body. There is an experiment being proposed where we can measure this in a novel manner, possibly during the launch, which has never been done before and also at various stages of adaptation to microgravity. Then there are psychological experiments in terms of how quickly we learn to cope without the presence of gravity and how is the performance of skilled tasks, which require small movement, affected.

> *"What everybody is gunning for is that if Juno is successful there would be a Juno-2 and a Juno-3 and a Juno-4."*

Then we get onto the non-biological side. There is some evidence that proteins, which are difficult to crystallize on Earth, maybe persuaded to crystallize in space and it might be possible to have bigger crystals. You need bigger crystals for X-ray and gamma ray neutron diffraction studies, to look at the structure of proteins. A pharmaceutical company will use this information to make lock and key type of drugs which actual fit the protein which is under question. The mission itself is not long enough to grow decent size crystals so it is conceivable that we might be allowed to leave something up there and get it brought back on another trip. But there might well be room for experiments that try to optimise the actual chemical and environmental conditions under which crystallisation occurs. So far people have only flown a few samples and only guessed at the conditions and concentration of substances. There is one experiment that has been proposed where hundreds or even thousands of combinations may be tried to see whether it would crystallise at all. Then on the next flight one would pick out the best conditions and then perhaps have a chance of actually growing bigger crystals.

Then there are metallurgy experiments: making alloys of mixtures of components with very different densities. There maybe semi-conductor purification experiments.

We ourselves have a very elaborate system for noticing which way up we are, the so called vestibular system. There is an experiment which measures the performance of the vestibular system. It should have flown with the British astronaut on the Shuttle mission and it looks that we might inherit it. The hardware for that exists so it is very attractive to us.

There is a group at the University of Kent who would like to collect some cosmic dust or at least make some observations of cosmic dust. There are difficulties about this because a cosmic dust detector should be by nature on the outside of the spacecraft and it is difficult to place anything on the outside of Mir because there is no EVA planned for this mission but we are looking at whether it might be possible to have a detecting system where one might use the outside of the Soyuz as the impact area for the particles.

So there is no shortage of experiments.

Of all these experiments which ones do you feel will produce the most exciting results?

Well being a biologist myself, I would have thought the egg and developmental biology ones would be the most interesting. But I think first its is not for me to choose and secondly science is full of surprises and something we think is quite a boring experiment might produce a rather interesting result.

Will there be any Earth observation experiments?

When we started Juno we were under the impression that it was essentially a microgravity mission. We did not know if we were even allowed to look out of the window, I mean other than on a sort of cursory basis. As a result of the recent meeting it was suggested that we might want to do that or even to use some of the facilities which Mir has, like cameras to take photographs. Now I have not done much about this. First it is not clear to me at the moment whether this would be an extra for which we would have to pay, I suspect we would have to pay.

You mention you have been offered the use of cameras. Have the Soviets offered you use of any other equipment such as a furnace?

Well they have not got a furnace at the moment. There was a furnace but it is not there any more. They plan to have a furnace that we might be able to use. They put it to us we might like to take a

furnace of our own. In fact I have been discussing with someone today that we might use some of the equipment that has been developed for Texus [a sounding rocket]. But one of the things about borrowing equipment is we cannot bring it back so we might have to get another one made.

Before docking there will be a period in the Soyuz capsule. Do you plan to utilise this time for experiments?

Yes. We have of course a problem because any experiments would have to be within the 20 kg of the upward journey. All I can conceive at the moment is that we might do some experiments on the astronaut himself, such as the fluid displacement one I mentioned before. We hope of course this time will be as short as possible, usually it is about a day because obviously you approach this docking fairly gingerly. It could be two days apparently. This interval is of importance to me because the endurance of the cold store for the sensitive biological stuff will have to take the worst case into account. On the way back we also have a time problem, it could be as little as four hours if everything goes well or it could be 28 hours because if they miss reentry they have to wait 24 hours to be in the right position again to land roughly speaking where they want to.

As the capsule reenters your samples will be subjected to g forces. Will you have to take precautions to prevent damage at this stage?

Well it is no worse than on the way up or not very much worse anyway. I draw a distinction between DCg and ACg. What we are subject to now is DCg. Of course as you accelerate and you decelerate there is a lot more DCg because you might be decelerating up to 7.5 g and if there is an abort trajectory, if something goes wrong, it could go up to 24 g, though not for long fortunately. Now little things like cells do not matter very much because by this time they have been fixed and the information has been imprisoned within them. So I am not really concerned about them. What is of more concern is vibration. During launch and recovery there are very high levels of vibration, this is the ACg part of it. I think most of the design problems we will have with the hardware is actually to get them to survive the vibration environment on the way up and this is where hopefully industry will be of use to us. We have some idea of how to get over this because our payload is usually pretty small. To cope with vibration on something which is not much bigger than a loaf of bread is of a different order to having a whole satellite to consider.

What do you hope British science is going to get out of this mission?

I have to keep emphasising to people that here you are going to do 48 hours of science under rather difficult conditions. We would be exceedingly lucky if we got a world shattering discovery out of this. The example I was quoting was that if you collected all the Noble Prize winning scientists in the world and you give them all, working together, a week in a laboratory and told them to make a discovery I think it would be unlikely a discovery would be made. Science works by taking relatively small steps towards knowing more. What I hope is that this mission will demonstrate that with relatively short lead times and relatively little money it is possible to fly worthwhile experiments. If we were able to show this I think we would then have opened a new market for an affordable space experiment market and this is of course what everybody is gunning for: that if Juno is successful there would be a Juno-2 and a Juno-3 and a Juno-4. There might well be a business in which industry and academia were increasingly prepared to pay for payload space in the same way they would be prepared to pay for an electron microscope. So it is very much a demonstration mission.

Do you think that British science and probably industry more so, have yet to realise the full potential of microgravity experiments?

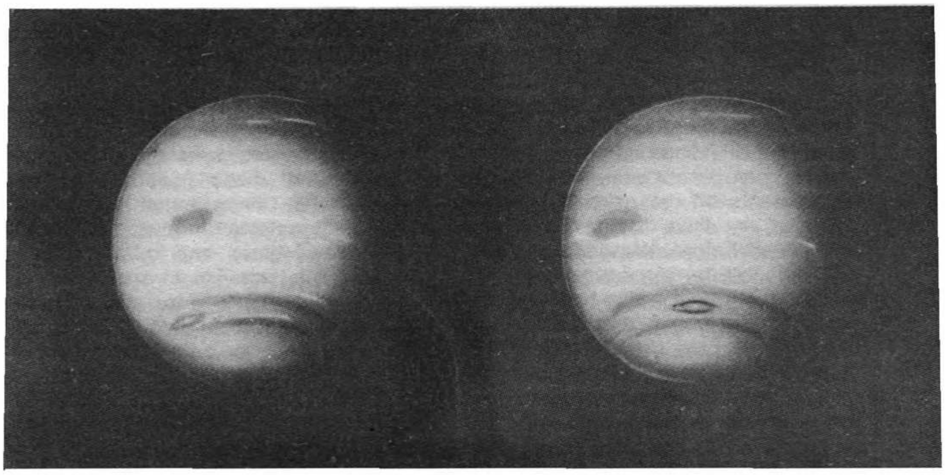
I am sure they have not. And I suspect that I have to also. I am sure we will find that there are some areas that are marvellously interesting and other areas that look very promising at the moment which turn out to be dead ends. I think people must not view this with expectations which are of a quite different order from the sort of expectations that they would have for a week in a laboratory anywhere else.

SPACE AT JPL

The latest news from Dr. William McLaughlin at the Jet Propulsion Laboratory in California.

Journey to Neptune

IN the year of 1846, when Neptune was discovered at the Berlin Observatory, the Smithsonian Institution in Washington and the Carl Zeiss optical factory in Jena were founded, Hector Berlioz's *Damnation of Faust* was first performed, in Paris, and Iowa was admitted as the twenty-ninth state of the Union. Time has been kind, on the whole, to these enterprises, except that Neptune has languished on the edges of scientific knowledge due to its great distance from Earth. In Pasadena in the year of 1989, this lapse was rectified as the flight team at JPL guided inquisitive Voyager 2 through the Neptunian system.



These two images of Neptune were taken by Voyager 2's narrow-angle camera when the spacecraft was about 12 million km from Neptune During the 17 6 hours between the left and right images, the Great Dark Spot completed a little less than one rotation of Neptune. The smaller dark spot completed a little less than one rotation, as can be seen by comparing its relative position in the two pictures
NASA/JPL

There are many perspectives on this event: scientific, engineering, historical and personal. At the 1986 encounter of Voyager 2 with Uranus, my job as engineering manager of the project naturally led me to focus on the second item in the above list (see the March 1986 edition of this column). For Neptune, I have had the luxury to step back and see some of the other elements as well. The steps of my particular journey to Neptune, listed below, are highly selective and depend a lot on what I happened to write in my daily journal. Also, they may give the impression that not much took place between Uranus and Neptune - not so, the cruise period is busy on Voyager and is the time when preparations are made for the next planetary encounter - but limitations of size dictated abridgment.

The number inside parentheses after each date in 1989 measures the distance of Voyager 2 from Neptune at 9 a.m. Pacific Daylight Time in millions of kilometres.

24 January 1986: When Voyager 2 emerged from behind Uranus and the radio-science ring-occultation experiment was completed, telemetry modulation was turned on again and engineering status checks showed that all was well.

25 January 1986: The "second pass" through the Uranian system was an enormous success. The tape-recorded best images of the satellites came down today and were well pointed and smear free. It was beautiful.

28 January 1986: The Space Shuttle Challenger exploded 73 seconds after liftoff.

10 February 1986: I reviewed the Mission Planning Office guidelines for Voyager 2's cruise to Neptune.

14 February 1986: Long 2.5-hour trajectory-correction manoeuvre for Neptune. Watched the Doppler residuals; looks like a good burn.

4 March 1986: Finished compiling the awards list of candidates from the engineering office - for Voyager/Uranus. They will be submitted to the project for approval.

18 March 1986: The Division manager, Norm Haynes, introduced me at his staff meeting as the new manager of Section 315: the Mission Profile and Sequencing Section. First official day is March 24, I'll phase out of the Voyager engineering office gradually as the new manager breaks in (Dr. Lanny Miller was selected and has done an outstanding job).

28 May 1986: I recommended Marie Deutsch to Lanny as Chief of the Voyager Sequence Team (JPL has a "matrix organisation" and technical sections, such as mine, staff flight projects, such as Voyager. Clearly, cooperation and mutual agreement are vital to the success of the relationship. My section staffs three teams on Voyager - Sequence, Mission Planning, and Science - and similar elements on projects such as Magellan and Galileo).

30 October 1986: Voyager meeting: engineers from Section 315 presented plans to the project for developing ground-software support for the capability of taking very long exposures at Neptune (where light levels are very low).

18 December 1986: Heard that Dick Laeser will be leaving as Voyager Project Manager, on to a Space Station assignment, and Norm Haynes will take his place.

27 January 1987: Dr. Frank Jordan was introduced as our new Division Manager, to replace Norm.

10 February 1987: At Norm's lunch, commemorating his move from Division to Project, I read a bad poem I had written to mark the event (I would be willing to read a good poem, but first I have to write one).

18 August 1987: Meeting with the Voyager project on NEET (Neptune Extended Exposure Task). George Masters has led the effort for our section and did great work: almost done with these changes to the ground software that will allow the spacecraft to shutter images for longer times in the dim and dark outer Solar System.

21 December 1987: Attended a presentation by some of our engineers to Voyager on the status of testing Neptune ring models that have been

installed in the remote-sensing-design program POINTER.

18 April 1988: Went to MIT's AI Lab, in Cambridge, Massachusetts to confer with Boris Katz on his natural-language program "START". He has been working with us for some time to devise more effective human/machine interfaces for space flight operations (see the August 1988 "Space at JPL"). We may test it, as a demonstration, during the Voyager/Neptune encounter.

14 March 1989 (236.7): Boris Katz is here at JPL for a week, and we reviewed the status of START.

28 April (171.6): Magellan launch scrubbed today due to problems with the Shuttle Atlantis.

4 May (162.9): The big, big events today were the successful liftoff of Magellan, followed by deployment from the Shuttle and injection into interplanetary cruise towards Venus. Now we have two in-flight planetary missions: Voyager and Magellan.

15 June (102.2): We held a Section 315 readiness review to assess our preparedness to support the Neptune encounter. Marie Deutsch led the review, and senior members of the section served on the review board (Galileo, Magellan, and other personnel). Lanny Miller represented the project. Looks good. From our perspective the Voyager project is indeed ready.

7 July (70.3): Neptune has a newly discovered satellite: 1989N1. Actually detected last month, it was just recently announced and joins Triton and Nereid.

11 July (64.5): A British crew, from ITV, interviewed me for JPL background material and history for a Voyager/Neptune documentary they are producing.

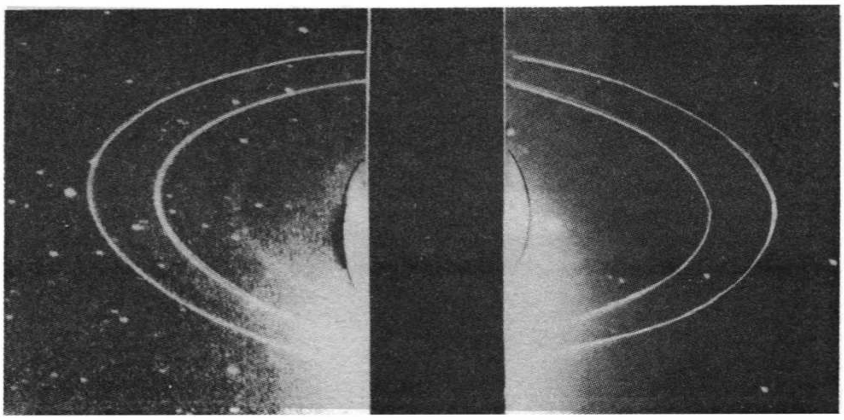
14 July (60.2): Met with Marie Deutsch on Voyager status. They are about ready to put the last (of 10) encounter sequences through the update process.

20 July (51.5): Today is the 20th anniversary of the landing of Apollo 11 on the Moon: lots of media retrospectives. President Bush outlined a general plan for future exploration of the Moon and Mars.

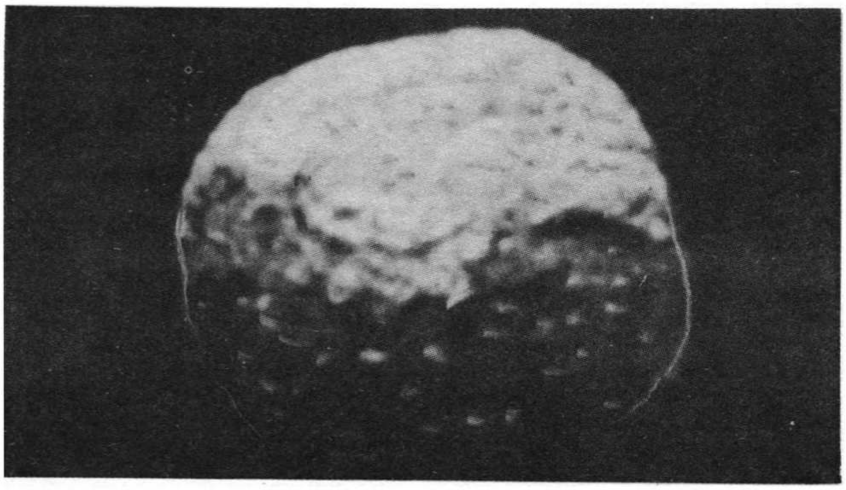
21 July (50.1): Two exciting images of Neptune were released. They show a variable white feature as well as an analogue of Jupiter's Great Red Spot which has been showing up on Voyager images for some time now. It is referred to as the "Great Dark Spot".

25 July (44.3): The monitors around JPL were showing an 18-frame movie of Neptune's atmospheric dynamics: lots of action.

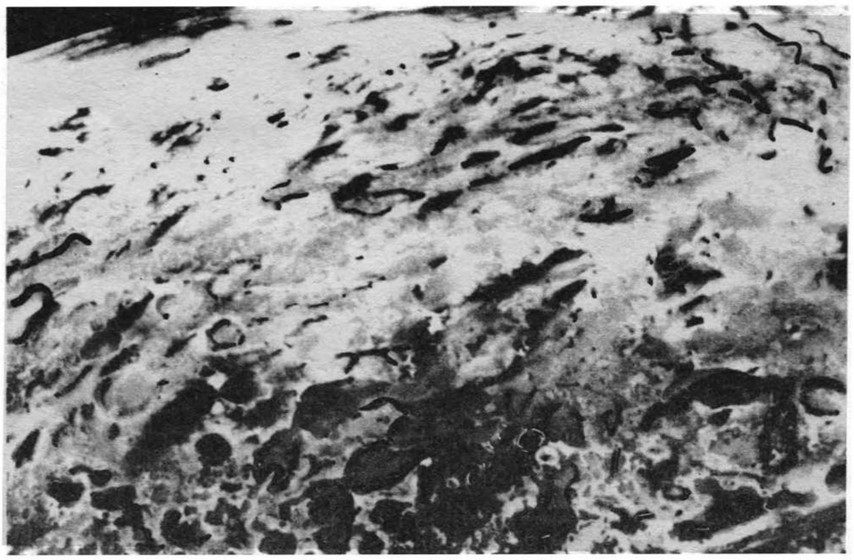
1 August (34.1): Two more images from the narrow-angle camera were released today: a colour rendition of



These two 591-second exposures of the rings of Neptune were taken with Voyager 2's wide-angle camera on August 26 at a range of 280,000 km behind the planet (plane angle of 135°). The two main bright rings are visible (53 thousand and 63 thousand km) along with a faint inner ring at about 42 thousand km and a broad plateau of material extending inward from halfway between the two bright rings *NASA/JPL*



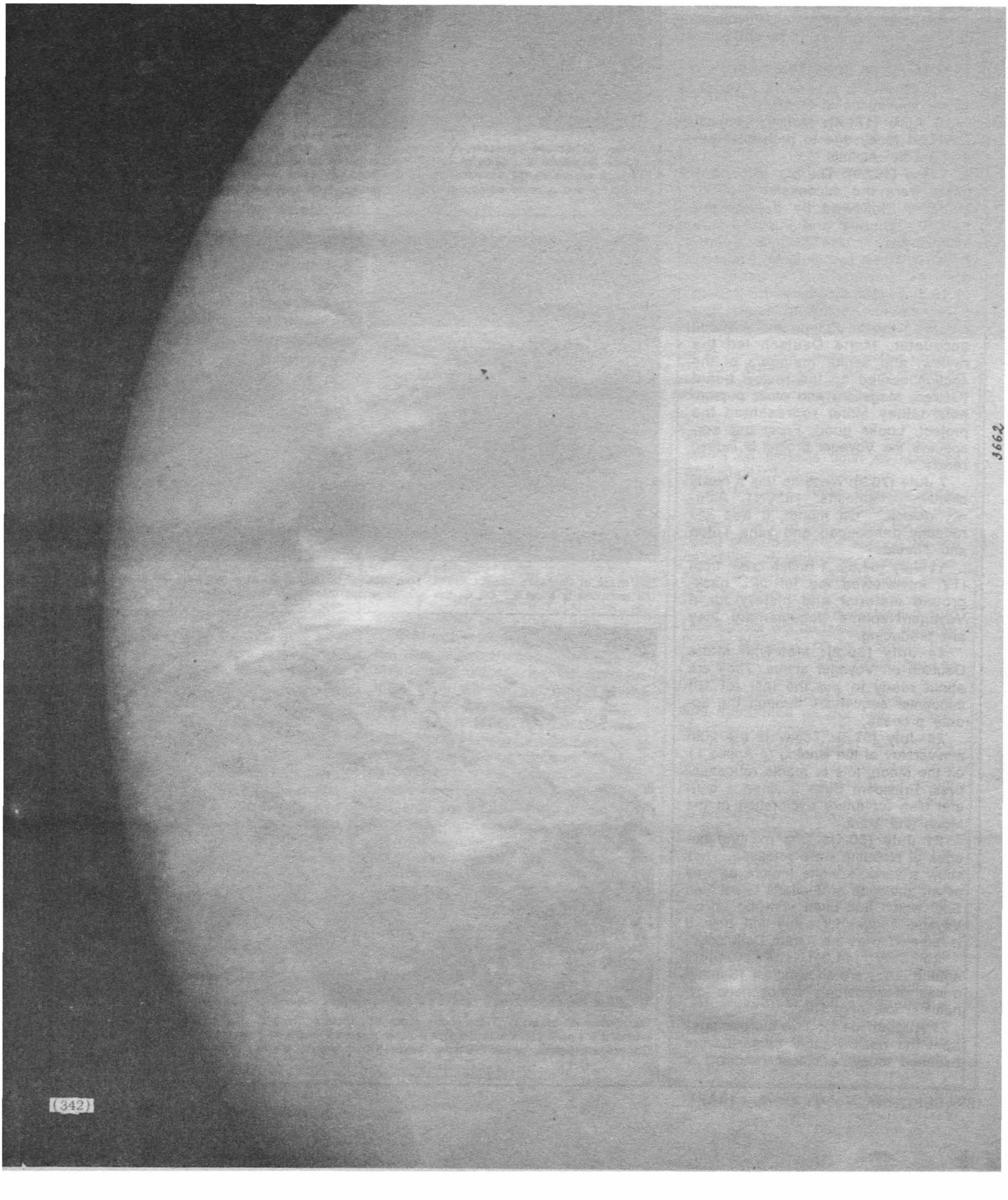
This image of Neptune's satellite 1989N1 was obtained on August 25 at a range of 146 thousand km. The resolution is about 2.7 km on this satellite whose diameter is approximately 429 km. *NASA/JPL*



The south polar terrain on Triton shows about 50 plumes or "wind streaks" on the icy surface. Those streaks are almost 200 km in length and could represent eruptions from outbreaks of "icy volcanism". The erupting particles would be blown across the surface by winds in Triton's nitrogen atmosphere. *NASA/JPL*

VOYAGER

AT NEPTUNE



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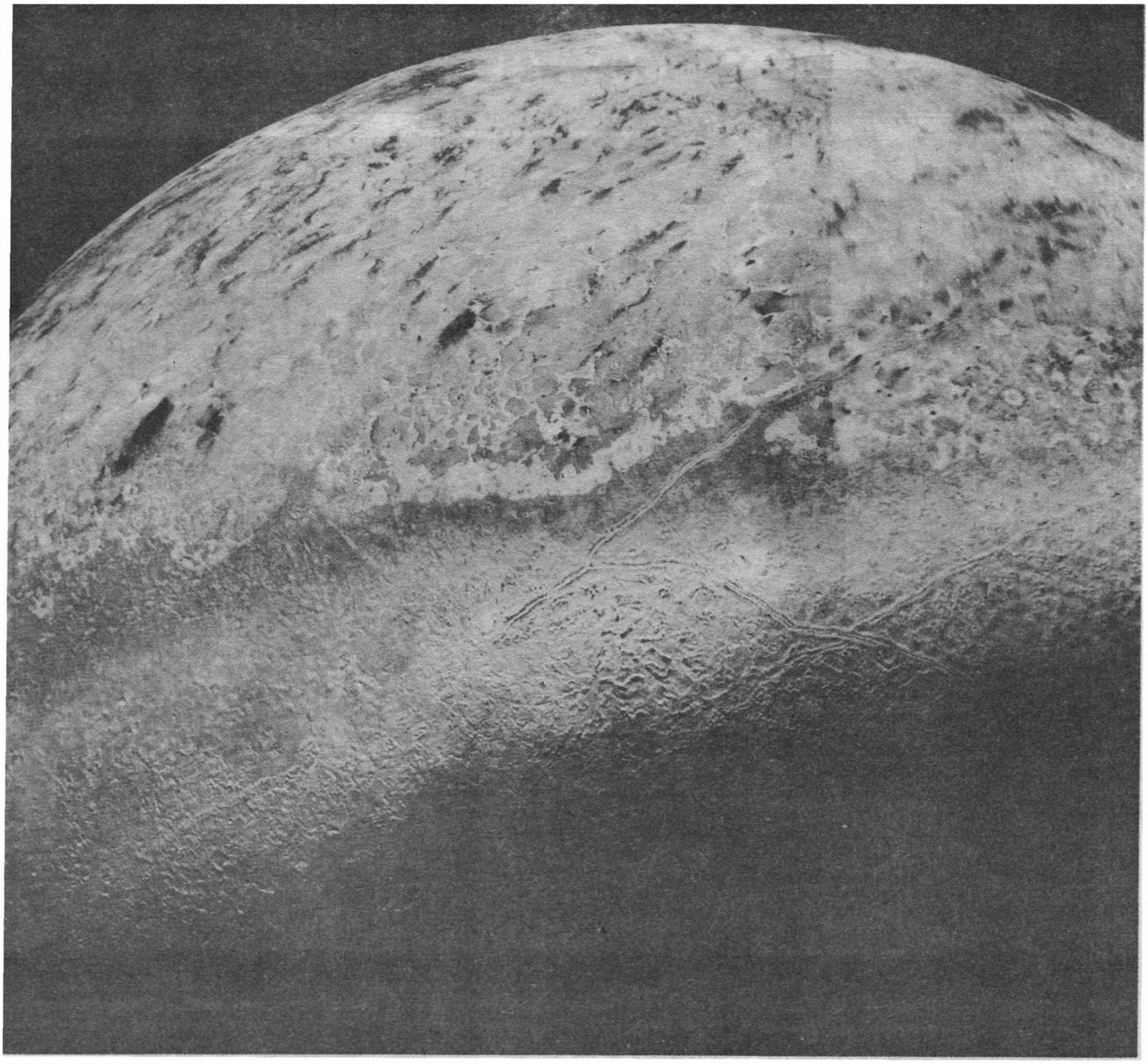
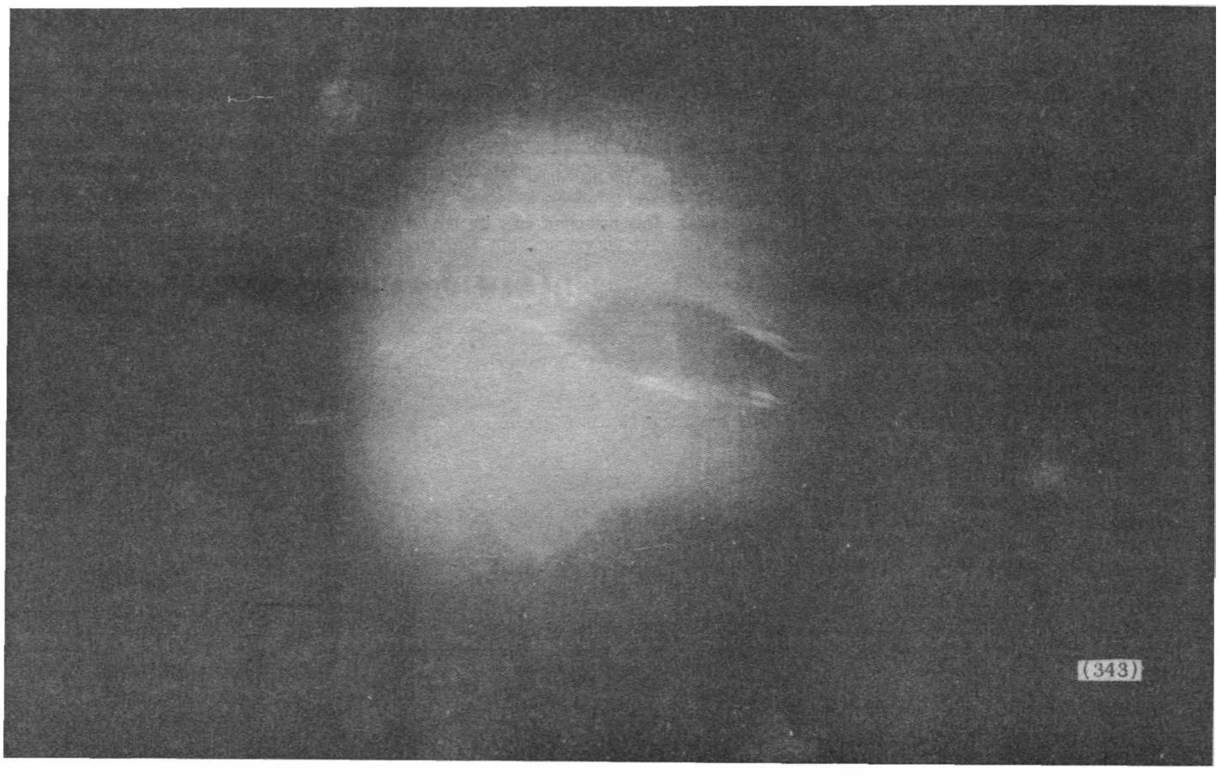




Triton and blue Neptune in one field of view (range of 47 million km) and a black-and-white image showing new detail in Neptune's atmosphere (a rapidly rotating dark spot within the southern "dusky collar" band).

2 August (32.7): George Masters and I discussed some options for Voyager ground-software development after Neptune: the Voyager Interstellar Mission (VIM). George is the system engineer for the Mission Sequence System - the software set that supports construction of command loads for the spacecraft.

3 August (31.2): Three more satellites of Neptune have been discovered. They join Triton, Nereid, and 1989N1.

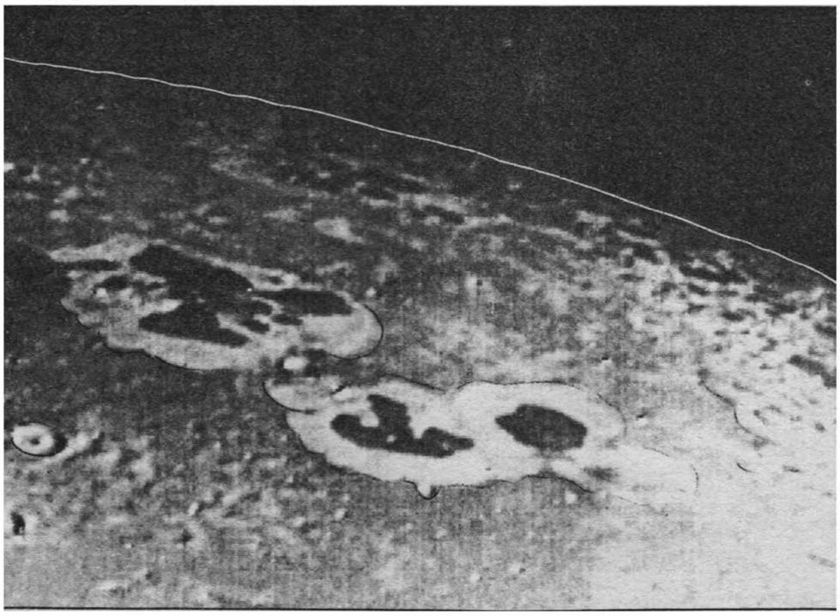
6 August (26.9): Ended "Observatory Phase" today and began "Far Encounter".

8 August (24.0): Got a first look at a Voyager 2 image of Neptune and all four of its new satellites: faint streaks of light framing the large, white (overexposed) glob of the planet.

11 August (19.7): The existence of two ring arcs has been confirmed. Both are in the equatorial plane and extend approximately 45° and 10° about the planet. The longer arc is just outside the new satellite 1989N4 and the shorter one trails the satellite 1989N3 by about 90°. Kathleen Mallis, our section's lead secretary, keeps our display case stocked with the latest Voyager images and they attract considerable attention (monitors in the JPL cafeterias are also good information sources).

16 August (12.4): A total lunar eclipse was visible here in the early evening. The dusky, orange-hued Moon heightened the sense of astronomical wonder which Voyager is generating.

17 August (11.0): From 6 a.m. to 12:30 p.m. I helped monitor a simulated Galileo/IUS deployment from the Shuttle, after launch. JPL, Houston, and Sunnyvale (from where the



A portion of the satellite Triton is shown in this view which is about 1000 km across The origin of the dark, irregular areas fringed by brighter material is not now known. *NASA/JPL*

IUS upper-stage is managed) participated and skilfully worked around simulated anomalies: "deploy" was successful. Walking out of the operations building, I encountered Jurrie Van der Woude, JPL's "picture man", and looked at some exciting new images of Neptune he was about to release; the resolution of wispy white clouds in Neptune's atmosphere has increased dramatically.

18 August (9.5): Radio emissions from Neptune have been detected by the spacecraft, and they indicate the presence of a planetary magnetic field. Also, there are indications that we will be able to see through Triton's atmosphere to the surface (unlike the case of Titan at Saturn). Hence, all the major components are shaping up for the encounter: atmospheric dynamics, magnetosphere, rings, and satellite morphology.

20 August (6.6): Len Carter and Shirley Jones arrived from London yesterday, and we met in the press area at JPL today. We looked at the START demonstration. It is in excellent form. Assisting Boris in the presentations are two of his students, Bob Frank and Jeff Palmucci, and Karen McLaughlin (she and I marked our 29th wedding anniversary today).

21 August (5.2): The first Voyager/Neptune press conference was held this morning in Von Karman Auditorium. Haynes said that today's small trajectory-correction manoeuvre went well, and the spacecraft should be positioned to view a dual occultation of Sun and Earth by Triton. This will probably be the last trajectory-correction manoeuvre done by either Voyager spacecraft. Dr. Brad Smith, Principal Investigator for the imaging experiment, speculated that the persistent features on Triton could be methane ice darkened by radiation. The surface of that satellite is probably too cold to host the lakes of liquid nitrogen which had been hypothesised by some scientists.

22 August (3.7): I spent today at the opening session of the 2nd AIAA/JPL International Conference on Solar System Exploration. It is being held a few miles from JPL on the Caltech campus and has brought together a "who's who" of individuals from the worldwide space community. The daily press conference from JPL was tape delayed and replayed in the main (Beckman) Caltech auditorium at noon. The basic features of the Neptunian ring system seem to be getting sorted out with further observations of the two arcs detected earlier. The inner "arc" is, in fact, a 360° ring: it

Centre Pages:

Left: This photograph of Neptune was reconstructed from two images taken by Voyager 2's narrow-angle camera, through the green and clear filters. At the top is the Great Dark Spot, accompanied by bright, white clouds that undergo rapid changes in appearance. To the south of the Great Dark Spot is the bright feature that Voyager scientists have nick-named "Scooter" Still further south is the feature called "Dark Spot 2," which has a bright core.

Top Right: Approximately a dozen Voyager images were combined to produce this comprehensive view of the Neptune-facing hemisphere of Triton. The large south polar cap at the top of the image is highly reflective and slightly pink in colour; it may consist of a slowly evaporating layer of nitrogen ice deposited during the previous winter. From the ragged edge of the polar cap northward the satellite's face is generally darker and redder in colour. This colouring may be produced by the action of ultraviolet light and magnetospheric radiation upon methane in the atmosphere and surface.

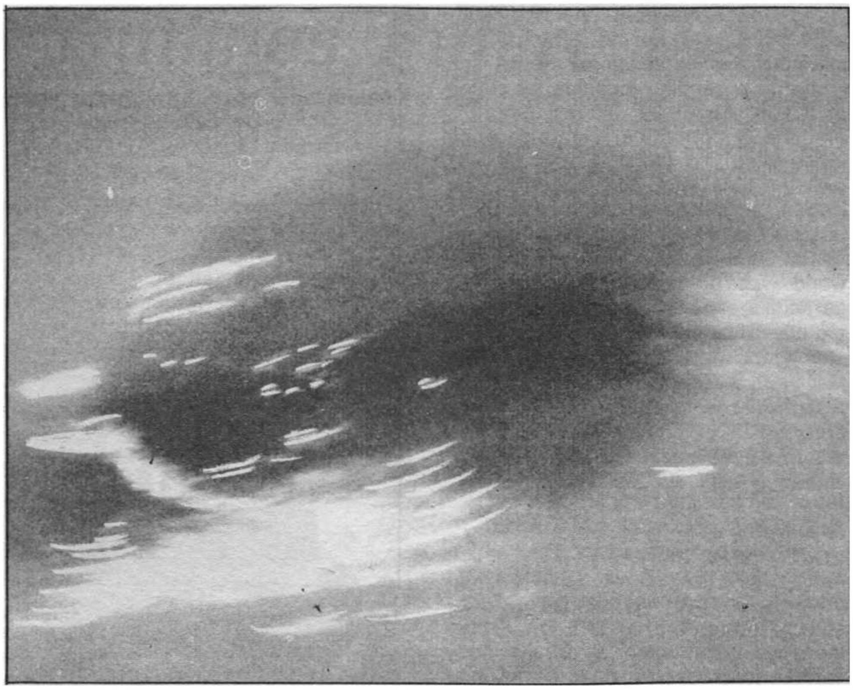
Bottom Right: This picture of Neptune was produced from images taken through the ultraviolet, violet and green filters of Voyager 2's wide-angle camera. This "false" colour image was been made to show clearly details of the cloud structure and to paint clouds located at different altitudes with different colours. The Great Dark Spot and the high southern latitudes have a deep bluish cast in this image, indicating they are regions where visible light (but not ultraviolet light) may penetrate to a deeper layer of dark cloud or haze in Neptune's atmosphere. conversely, the pinkish clouds may be positioned at high altitudes. *NASA/JPL*

completely encircles Neptune. Being quite faint, it was probably not involved in previous stellar-occultation observations conducted from Earth. The outer ring is still seen as a partial arc (but Brad Smith thinks we may later detect material everywhere in it) of variable density. Thus, the multitude of partial arcs which were invoked to explain one-sided occultations seen from Earth probably have found their true home in this one, inhomogeneous locus.

23 August (2.3): No major discoveries today, but the epistemological veil separating us from the Neptunian system continues to dissolve. The dark bright albedo features on Triton are becoming more distinct, but until we can resolve them into geological features their origin remains obscure. They could be controlled by topographic features or, Brad Smith conjectured, might relate to sublimation and deposition of nitrogen and methane ices - frost - with a background of radiation-discoloured methane ice. A blue fringe of the satellite is also puzzling; blue is an unexpected colour here. A possible origin is Rayleigh scattering from small, submicron crystals condensed on the surface. (The scattering on Earth that makes our sky blue is governed by gas molecules.) Norm Haynes reported that tracking subsequent to Monday's trajectory correction manoeuvre has shown the trajectory to be on target for the dual occultation. The Solar System Exploration Conference at Caltech delivered a second day of excellent papers on human and robotic exploration.

24 August (0.78): Two new satellite discoveries were announced today, 1989N5 and 1989N6, and the first of the newly discovered satellites, 1989N1, proved to be very irregular in shape, considering its relatively large size, upon close-up viewing.

At Caltech, Dr. Eleanor Helin and Ron Helin hosted a lunch in the Athenaeum (faculty club) Library. Bruce Murray spoke before lunch about how he came to write his newly published book *Voyage Into Space*. After lunch, Clark Chapman, Al Hibbs, and I each said a few words about Voyager.



This image of the "Great Dark Spot" was shuttered with the narrow-angle camera 45 hours before closest approach at a range of 2.8 million km. The smallest visible structures are about 50 km in size.
NASA/JPL

NASA Administrator Richard Truly addressed the Solar System Conference at Caltech and spoke of the future: "Over the next few decades a string of wonders such as mankind has never seen before will unfold". Turning to the present he said: "We, like children, have learned through Voyager's eyes. Surely this is a day to remember". The spacecraft entered the magnetosphere of Neptune around noon (PDT).

Back at JPL, coverage by the news media was intense as scores of journalists waited through the evening to glimpse ever higher resolution images and listen to project reports over the in-house Voyager television network. About 9 p.m. I went into science support areas in Building 301 (VNESSA: Voyager/Neptune Encounter Science Support Area) where Principal Investigators and their Co-Investigators from Voyager's experiments reviewed and analysed data during this crucial period: space scientist Dr. James Van Allen and Dr. Lennard Fisk, Associate Administrator of NASA's Office of Space Science and Applications, were in the area. Crossing the street to Building 264, I went up to the Voyager project office on the fourth floor and, in company with Lanny and Sylvia Miller, watched some tantalising Triton images from several hundred thousand kilometres. The project had soft drinks and food prepared for the night's vigil. On to a third node of activity: the JPL press room in Von Karman. There, just before midnight, we watched telemetry present evidence of a rapid increase in particle impacts as the spacecraft crossed Neptune's equatorial plane, wherein the rings lie. Crossing seemed OK, and soon after the telemetry was turned off as the spacecraft prepared for its radio-science experiment.

24 August (as close as 29,230 km to the centre of Neptune) "Today" is merely a formal convention. I gave up the idea of sleep as foolish and went from the press area to my office to write these notes just after midnight. Closest approach to Neptune was about 1 a.m., but the spacecraft was then too deep in thought to comment as it conducted a radio-science experiment by sending radio waves through the atmosphere of Neptune, to be refracted and received by the

NEPTUNE'S NEW MOONS

TEMPORARY NAME	ORBITAL RADIUS	ORBITAL PERIOD	ORBITAL INCLINATION	DIAMETER (ESTIMATED)
1989N1	117,600 km	26.9 hrs	<1 degree	420 km
1989N2	73,600 km	13.3 hrs	<1 degree	200 km
1989N3	52,500 km	8.0 hrs	<1 degree	140 km
1989N4	62,000 km	9.5 hrs	<1 degree	160 km
1989N5	50,000 km	7.5 hrs	<1 degree	90 km
1989N6	48,200 km	7.1 hrs	~4.5 degrees	50 km

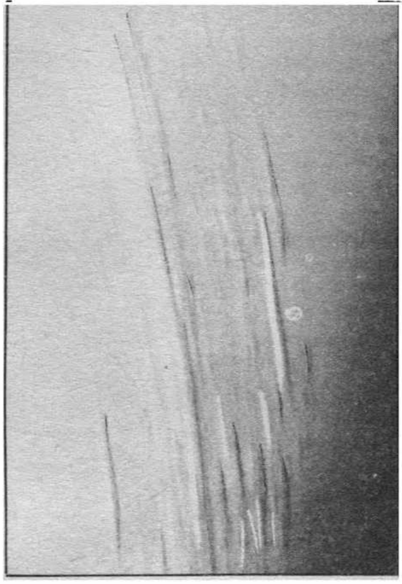
Deep Space Network, yielding valuable data relevant to atmospheric structure and composition. Karen and I went to a vending machine for coffee at 2 a.m. About 20 minutes before 3 am, the spacecraft's telemetry once again filled the monitors and all was well. An hour later, the featured event began: a series of high-resolution images covering the lighted disk of Triton. The panorama of this new world was presented chunk-by-chunk as its frozen hills, flows, "maria", and craters filled the television monitors. Our visual neurons were happy - we had seen the surface of Triton. And as a rather cool August morning was breaking in California, the dual occultation of the spacecraft by Triton concluded a very successful night.

Afterward

Of course there was very much more than the above sketch could cover. As the regular workforce started appearing at JPL on Friday morning, I instructed all of my body centres to proceed just as if they had benefited from a full night's sleep; management by directive will work on occasion. In midmorning, Vice President Quayle addressed a large and enthusiastic JPL crowd on the Mall. He congratulated the Voyager flight team on their achievement and spoke about President Bush's new initiative for NASA, first enunciated in a speech on 20 July, to go to the Moon and Mars with robots and humans. That evening Karen and I went to dinner with Boris Katz and his colleagues to talk about the encounter and the success we had enjoyed during this time with the START natural-language demonstration. Saturday night we added to the calorie count by dining with Len Carter and Shirley Jones where Neptune was the fifth guest at the table. On Sunday, I was able to go to the third day of the Planetary Society's very fine "Planetfest" in Pasadena. They also presented a celebration of Voyager on the JPL Mall on Sunday evening.

Each day at 10 a.m., throughout the encounter, press conferences were held for about two hours and gradually brought forth some scientific structure to the myraid of data that had flowed down in the last few weeks. A brief summary is given below, but theories will evolve and new insights will be obtained, so a stable narrative will not be possible for some time. It is convenient to divide the scientific results into the four categories of planet, rings, satellites, and magnetosphere.

The most apparent feature of the planet was the existence of significant, visible atmospheric dynamics: weather. A goal of the atmospheric investigation was to determine the magnitude and direction of prevailing winds, but this proved very difficult because most cloud formations mutated rapidly, making it hard to compile their drift rates. However, using four reasonably stable features yielded a wind-velocity profile *versus* latitude: a maximum speed of about 325 m/s was achieved at the latitude of the Great Dark Spot. Thermal data revealed that Neptune is warmest at the equator and poles and coolest at midlatitudes. A rotation of approximately 16*h* 03*3m* (± 04*m*) was determined by timing ratio emissions from processes deep inside Neptune. There was evidence for auroral activity (but not imaged by the cameras) on both Neptune and Triton (the latter lies within the magnetic field of Neptune).



Taken two hours before closest approach, this high resolution image of Neptune's cloud steaks shows vertical relief in the structures The resolution is about 11 km at this range of 157,000 km The widths of the streaks range from 50 to 200 km & the heights are about 50 km. *NASA/JPL*

With hints of rings or ring arcs having been obtained through ground-based observations, interest was particularly high in this area. There is an outer clumpy ring ("Main Ring") reminiscent of Saturn's F ring, at about 63 thousand km from the centre of Neptune and two other rings at 53 thousand ("Inner Ring") and 42 thousand km ("Inside Diffuse Ring"). Between the two outer rings a "plateau" (annulus) of material begins and extends several thousand km inward. The two outer rings were the first discovered by Voyager, and the third ("inside") ring is quite faint. The three rings are quite dusty while the annulus contains only about 10% dust.

The equatorial plane of Neptune carries, in addition to its complement of rings, a multitude of micron-sized dust particles which impacted the spacecraft at rates up to 300 per second - no damage was observed. These particles were most likely created by the abrasion of satellites and ring particles by micrometeorites.

As expected, Triton was the subject of principal interest in the system of satellites. Its diameter, at about 2,720 km, is smaller than had been predicted on the basis of its brightness seen through a telescope. But icy Triton reflects far more sunlight (approximately 70%) than expected, thus producing the impression of greater size as viewed from Earth.

The topography of this distant world is diverse and complex. It has none of the mountains and chasms of the Uranian satellite Miranda; most elevations are on the order of 100 m. Triton is a bas-relief sculpted in ice. Water ice is, in fact, the dominant material visible on the surface. There is an admixture of methane and nitrogen ices.

The complexity of the topography is derived from several processes: ice flows, sublimation and deposition of material, flooding, cratering (crater counts for Triton approximate those of the lunar maria), and possibly ice volcanism. Evidence for the latter process is ambiguous - several dark streaks on the south polar cap that could be wind-blown plume deposits - but the idea, if it holds up, would add Triton to the example of Io for active extraterrestrial volcanism. ("activity" is inferred from the condition of the surrounding terrain.)

This icy satellite has a density in the neighbourhood of two grams per cubic centimetre and is enveloped in an atmosphere consisting largely of nitrogen.

The magnetic field of Neptune is similar in many ways to the one revealed by Voyager 2 at Uranus. The strength of the dipole component of the magnetic field is somewhat less than that of Uranus and exhibits, like Uranus, a significant inclination to the spin axis of the planet: about 50^0 (Uranus was 60^0). Another resemblance to the seventh planet was provided by the offset of the dipole from the centre of the planet. The flux of charged particles was reduced from that observed at Uranus. In all, the magnetospheric results were of considerable scientific interest but led to the characterisation: "Neptune's magnetosphere is rather humble".

Not only do we now have considerable scientific knowledge of each of the four gas giants as individual objects, but theories of origin and development will be furthered through the lens of comparative planetology. Goodbye Voyager 1, goodbye Voyager 2. Stay in touch.

JPL Director Outlines Future Plans

THE British Interplanetary Society was represented at the Jet Propulsion Laboratory in Pasadena, California, on the occasion of the successful Neptune Fly-By, by both its Executive Secretary and Deputy Executive Secretary. An account of discussions with Dr Lew Allen, Director of the Jet Propulsion Laboratory, appears below.

How do you see the future role of JPL?

I envisage proceeding down the line with our programme of approved and planned spacecraft. We have defined a very active programme over the next decade which addresses the most challenging and difficult missions in the exploration of the solar system.

We are contributing to the Freedom Space Station, examining what kind of science could be done at a lunar base and defining studies on the human exploration of Mars. Our precursor studies, before the manned Mars landing, include the Mars Rover and high-resolution orbiter missions.

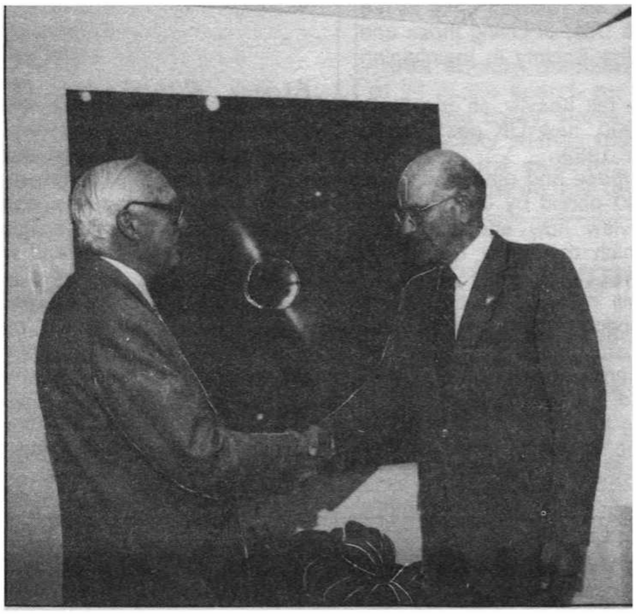
In JPL we have a staff of people able to contribute in a major way to a range of related activities such as solar system exploration and Earth remote sensing. We have scientific and engineering expertise and the skills developed in mission engineering to support such programmes.

As regards our own interests, the exact course would be determined by the President's initiative but there are a range of topics we would hope to address.

Generally speaking, these would include:

1. A range of scientific spacecraft to explore the solar system.
2. We are equally interested in solving significant global problems, for man's activities in the long run are not likely to be inimical to his environment.
3. We are involved in four major observatory satellites. A good amount of design work has been done and they all have a good chance of going, e.g.

   (a) The Hubble Space Telescope, due to be launched by the Shuttle next year.
   (b) Gamma Ray Satellite, which is now practically ready.
   (c) AXAF, an X-ray observatory approved last year.
   (d) SIRTF, a space infrared telescope facility.
4. As a longer term interest, we would continue to evolve scientific techniques helpful in the search for possible Jupiter-sized planets around some of the nearer stars. We are already studying interferometry methods, direct imaging and astrometric techniques.



Dr Lew Allen, Director of JPL, (right) meets the Society's Executive Secretary, Mr Len Carter.

Will the future work of JPL embrace more Applications of Space Science and Technology?

We fully support the NASA programme for Mission to Planet Earth which will greatly improve the data available and the ability to understand the planet in terms of global change.

The techniques and scientific expertise we have developed for observing the planets can be applied to the Earth also, to determine global and synoptic changes.

Examples of the work we have done in this area are Topex, a collaborative project with France, and the scatterometer to measure wind fields above the oceans. We also have studies in hand on atmospheric sounding - to give profiles of temperatures, pressures and atmospheric constituents - and Synthetic Aperture Radar which should prove most useful in assessing such matters as sea ice and biomass.

The OSSA Strategic Plan for 1989 refers to a strategy to be pursued for the next 5-10 years and states that a major objective will be to initiate a programme of excellence in the study of comets and asteroids. How do you see such a programme developing?

Apart from CRAF, which is really a precursor mission and Cassini, which will use a Mariner Mark II, we have on hand a number of studies of interest such as Caeser, a multi-asteroid mission. There is a need to study further comets either by orbiting or by lunar observatories, and there is a need for fly-through missions which are slow enough to collect particles. Most of the comets are fairly old but some are not, for example Wild 2 is a comparatively recent acquisition which was only kicked into its present orbit by Jupiter a few years ago.

Do you see a developing role for international participation in these programmes?

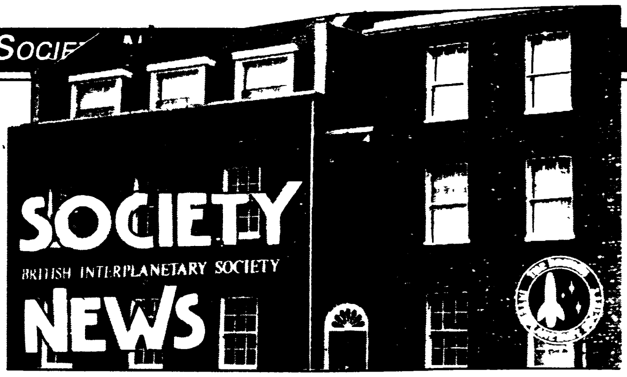
It is difficult to imagine any significant future programmes which do not involve international cooperation though it is necessary in every case to define carefully the exact nature of the cooperation.

We already have two very important collaborative projects with ESA, Galileo and Cassini, and I have every confidence that these will continue.

How would the offer from the USSR for a joint programme for the exploration of Mars fit into these plans?

My first impression is that the proposed Mars project seems premature. The practical complications of bringing the US and USSR together in such an arrangement are very significant. We also have to recognise that extreme economic conditions could arise which have to be allowed for so that any decision to go ahead would have to be as practical as possible, for subsequent financial adjustments can be very painful.

I feel sceptical about any arrangement whereby two separate parts are agreed which need to meet, at some future time and place, to be joined together. A better arrangement would be such that, if one party dropped out, the work of the other could continue and would not be wasted. ASTP, for example, was deliberately done so that the interface was as simple as possible.



1990 Subscription Rates

All members will be pleased to know that the subscription rates for 1990 will be the same as for 1989, in spite of the intervening rise of nearly 9% in the Cost of Living Index and a corresponding rise in costs to the Society in maintaining services to members.

Publication and postal charges fall heavily on the Society and will both be higher in 1990, new UK postal rates having taken effect in September 1989.

The Society intends to absorb these and other forthcoming cost increases during the 1990 period by internal cost-saving practices and then to review how effective these have been and the extent to which they may be carried forward to the following year.

An over-riding consideration will continue to be that of maintaining a high standard of service to members and the best value possible in relation to what the Society charges. The Society is confident that members will endorse this stance and welcome the holding of 1990 subscription rates at their present levels. US dollar rates will be subject to variation according to the exchange rate, as they have been in the past.

Queen's Birthday Honours

Our congratulations go to two members of the Society on receiving recognition in the Birthday Honours List.

The CBE has been awarded to Arthur C. Clarke, an Honorary Fellow and Past President of the Society, for services to British cultural interests in Sri Lanka. For many years Arthur Clarke has been a resident of Colombo and holds the position of Chancellor of the University of Moratuwa, Sri Lanka.

The MBE has been awarded to Paul Waters for his contributions as a Higher Telecommunications Technical Officer working for the Ministry of Defence. He is employed as a civilian at RAF Henlow, Bedfordshire. His previous working locations included the Navigational Aid Station on Truleigh Hill, near Shoreham, Sussex.

New Society Sign

We are pleased to report that a completely new and most attractive name sign is now in place at the front of our building. So familiar was the earlier sign that it was used by London Taxi Drivers as a point of reference, or landmark, in finding their way about and was taught as such in the Taxi Drivers School.

The removal of the earlier sign, due to damage from the elements, brought forth a number of telephone calls and enquiries from irate taxi drivers who wanted to know why it had been taken down and when it was going to be put back again!

The photograph of the Society's HQ which often appears at the beginning of *Society News* shows the conspicuous appearance of the sign.

SOCIETY MEETINGS DIARY

Technical Symposia

27 September 1989 10.00am-4.30pm

BRITISH SOLID PROPELLANT ROCKETRY

The emphasis will be on British post-war solid propellants and the development of associated rocket motor and launch vehicles.

Papers to be presented will have the following themes:

Congreve - by E.J. Becklake
Double Base Propellants - by E. Baker
Composite Propellants - by D.G. Catton
Early Solids - by S.W. Green
Gosling - by E. White
Sounding Rocket Motors - by J. Rolfe
IMI Motors - by S. Gordan
Stonechat - by P. Moore

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

Registration
Forms are available from the Executive Secretary. Please enclose a SAE.

Lectures

4 **October 1989 7.00-8.30pm**

BEHIND THE SCENES WITH MAGELLAN, VOYAGER AND GALILEO

Interplanetary exploration is showing a strong resurgence in 1989 with three major events leading the way: The Magellan launch to Venus, Voyager 2's flyby of Neptune and the Galileo launch to Jupiter. Bill McLaughlin, who is involved with all three projects at the Jet Propulsion Laboratory, will outline the missions and provide insights into the actual progress and results to date of these three endeavours.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope. Subjet to space being available members may also apply for a ticket for one guest

1 November 1989 7.00-8.30pm

CETI OVERVIEW - AN UPDATE

A. T. Lawton

Recent observations have revealed that at least two nearby stars have "Brown Dwarf" mini-stars as companions. Such studies will undoubtedly lead to the discovery of Brown Dwarfs as individual single stars, so that Proxima Centauri may not be our nearest extra-solar body.

The impact of these new discoveries on the more conventional ideas of CETI will be discussed.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope. Subjet to space being available members may also apply for a ticket for one guest

LIBRARY OPENINGS

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. Membership cards must be produced.

Society's Coat of Arms

We haved received an interesting suggestion from Andrew Achaber of Illinois, USA,:

> On the top, left hand side of my 1989 membership renewal form was a remarkably beautiful article of heraldry. Is the Society planning to have a sew-on patch of this design made?

This suggestion has been followed up and details of purchase will be included on the 1990 membership renewal form which members will be receiving shortly.

The history of the Society's coat of arms can be found in ***Spaceflight***, March 1987, p.121.

Space Collection Opens in Australia

The establishment of a Reference Centre of historic space materials at the Canberra Deep Space Communications Complex in Tidbinbilla has been brought to our notice with the close involvement of a number of Fellows of the Society.

This Complex played a major role throughout the Apollo Program and is today one of three key NASA space tracking facilities around the world. Appropriately, the centre was opened to coincide with the twentieth anniversary of the Apollo 11 lunar landing.

The Reference Centre is available for use by researchers and others with an interest in the history of space programs. Many items come from the collection of the late Mr Neil K. Kroschel, a former space science lecturer for NASA and Fellow of the Society.

BIS Members Amongst Juno Finalists

Three Society members have reached the short list of 24 in the search for Britain's first astronaut. They are David Eyley, Derek Greer and Christopher Welch. The Society wishes them well as they enter the next phase of the selection process. (See p.334 for a six page feature on the Juno Mission.)

Society Symposium Success

Over 50 members attended the Society's Soviet Space Symposium held on June 3,1989, the latest in a series held annually since 1980 which regularly attracted great interest from members.

Rex Hall, who chaired the proceedings, began by calling for more openness on the part of the Soviet authorities, for, although 'Semi-Glasnost' had reached the Soviet space programme, there were still many areas cloaked in secrecy. Western observers, too, he added, have a part to play by sharing information with their colleagues.

A whole range of papers was presented which reviewed both past Soviet space activities and a look forward to Soviet future plans.

The programme included a short Soviet film which provided a history of Mir and a glimpse of everyday life aboard the station. Also included was interesting footage of the launch of the Energia booster.

The meeting took place during a lull in the Soviet space programme, with the Mir space station unmanned, the second Phobos failing and budget cuts threatening the Soviets' ambitious plans. It was pointed out that only the new openness in the Soviet Union had enabled us to learn of these difficulties in detail. The popular press had branded the Phobos expedition a disastrous failure, though, in reality, this ambitious mission had achieved many of its goals. The meeting closed with a lively discussion about the budget cuts faced by the Soviet space programme and their probable effects.

The symposium provided an excellent opportunity for those interested in the Soviet space programme to exchange ideas and information. Models built by Phil Mills were of particular interest. They included the Mir space station with its modules, the SL-16 Zenit booster and the Shuttle preparation facilities at Baikonur.

The following papers were presented at the 1989 Soviet Space Symposium:

Soviet Space Communications - J. Branegan, *Soviet Manned Space Platform Project of 1963* - B. Harvey, *Soyuz 6, 7 and 8 crewing* - G. R. Hooper, *Soviet Spacesuit Design and Evolution* - D. J. Shayler, *How to Handle Cosmic Rays: Recent Thinking in the USSR* - P. A. Hansson, *Soviet Exploration of Mars and Phobos* - P. R. Bond, *Energia/Shuttle at Baikonur* - P. Mills and *Recovery of Salyut 7* - P. S. Clark.

JBIS

JBIS journal of the british interplanetary society

The October 1989 issue of the Journal of the British Interplanetary Society is now available and contains the following papers.

SMALL MISSION SYSTEMS

EPSILON TECHNOLOGY AND BIOLOGY IN SPACE ENGINEERING

MICROSPACECRAFT MISSIONS & SYSTEMS

CHEMICAL LAUNCH SYSTEM OPTIONS FOR MICROSPACECRAFT

CAMERAS FOR MICROSPACECRAFT

INFORMATION STORAGE AT THE MOLECULAR LEVEL: THE DESIGN OF A MOLECULAR SHIFT REGISTER MEMORY

ELECTRON TUNNEL SENSOR TECHNOLOGY

FAST, CHEAP AND OUT OF CONTROL: A ROBOT INVASION OF THE SOLAR SYSTEM

LUNAR GET-AWAY-SPECIAL: EXPLORING THE MOON WITH A MINIATURE, ELECTRICALLY PROPELLED SPACECRAFT

GAMMA-RAY BURST LOCALISATION WITH MICROSPACECRAFT

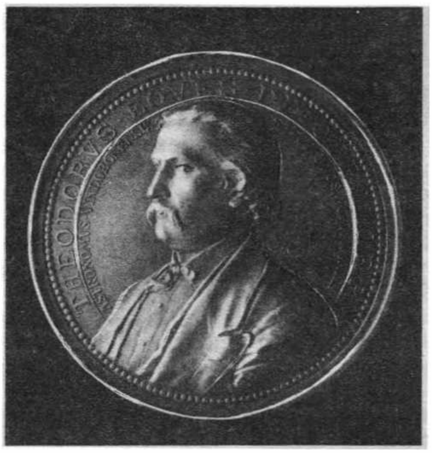
Copies of JBIS, are priced at £12.00 ($24.00) to non-members, £4.00 ($8.00) to members, post included, can be obtained from the address below.

Theodor von Oppolzer - an interesting Medallion

The Society has acquired a most interesting addition to its collection of space-related Medallions, this one being inscribed to Theodor von Oppolzer (1841-1886). It contains a fairly long and somewhat curious inscription in Latin, a literal translation of which reads as follows:-

> "This token is bestowed for loyalty displayed by a contemporary authority on matters concerning stars.
>
> These have been keenly investigated and frankly discussed and delivered at meetings in worldwide "Branches of Astronomy."
>
> It is also bestowed for loyalty in carrying out the rulings and will of the State and its ambassadors united in defending all of distinction and their wives and relatives from premature death, seizure (kidnapping as a hostage) or robbery.
>
> Given and dedicated as a gift to Theodor Knight of Oppolzer
> Astronomer of Good Character - In this age of 19 (centuries) after the Birth of Christ"

It seems apparent the medallion must have been received from the hand of the Austrian Emperor, Franz Joseph, himself for no one other than the Emperor could confer such a title of Knight. The nearest UK equivalent is a "Life Peerage", carrying with it a coat of arms and family motto.



We would be interested to hear from any readers able to throw further light on the matter.

Oppolzer had a most distinguished career. Using only a seven-inch refraction telescope he had, by 1866, published more than 77 papers on astronomy, comprising observations and computations of the orbits of comets and asteroids. In 1868 he participated in the Austrian solar eclipse expedition and in 1874 observed the transit of Venus. By 1875 he was full Professor of Astronomy at the University of Vienna and in 1873 Director of the Austrian Geodetic Survey. In 1886 he was elected vice-President of the International Geodetic Association.

In all, Oppolzer wrote more than 300 papers. As early as 1864 he was developing new formulas for calculating orbital elements and his two-volume *Lehrbuch zur Bahnbestimmung der Cometen und Planeten* (1870-1880) comprises all the materials then necessary for understanding and determining both preliminary and definitive orbits, with basic concepts, mathematical tools, practically arranged formulas, extensive auxiliary tables and examples drawn from the author's own experience.

In 1868 he began to study the computation of ancient and modern eclipses. This involved devising new methods and tables and, partly at his own expense, he began the immense project which resulted in the *Canon der Finsternisse* which contains, with minor exceptions, relevant data on about 8000 lunar and solar eclipses, with charts of the central parts of the latter, from 10 November 1207 BC (Julian Calendar) to AD 17 November 2163 (Gregorian Calendar).

Obituary - William F. Temple

It is with deep regret that we record the death at the age of 75 of William F. Temple who was one of the Society's early members in the 1930's and who helped with the design of a proposed multi-stage rocket, which the Society published in 1939. Among the early Society members of that time was Arthur C. Clarke with whom he shared a flat in London and an enthusiasm for science fiction.

William Temple became widely known as a science fiction author of over 100 short stories and nine books published between 1935 and 1968. Interplanetary travel featured frequently in his writings which often came close to predicting the way that man's exploration of space would develop.

Arthur C. Clarke pays the following tribute:-

WILLIAM F. TEMPLE
(1914-1989)

"Just three days ago I received a letter from Bill Temple that he had started to write on June 14, and completed with great difficulty, over a considerable period, with several different pens. A note from his wife Joan reported that he was back in hospital yet again.

Because the letter had taken two weeks to reach me and Bill's condition appeared serious, I phoned immediately. How glad I am now: to my delight, Bill was back home and I was able to have a brief but cheerful conversation with him. I guessed it might be our last but did not suspect how soon this would prove to be the case; he died peacefully, sitting in his chair, at home, on July 15.

In that last conversation I was touched to receive the best - if not the *only* - compliment Bill ever paid me. He had just received my "science-fictional autobiography", *Astounding Days*, which contains a chapter devoted to the famous 'Flat' we shared (with Maurice Hanson and, later, Joan Temple) at 88, Gray's Inn Road, in the years immediately before the War. "When I'd finished it," he said, "I went straight back to the beginning and read it again." I have never received a tribute I shall value more highly.

This is not the place to speak of Bill's contributions to the early days of the British Interplanetary Society as Editor of its *Bulletin* or of his literary career, truncated by War, illness and sheer bad luck. But I can recall that in the 1937-8 period most of us aspiring young writers looked up to him and his advanced years (he was already a mature 24!) with something like awe. And when he sold his novel, *The Four-Sided Triangle* to the *movies*, our admiration and envy knew no bounds.

Bill was the sort of friend every man needs, especially if - as in my case - he had occasional delusions of significance. I send my deepest sympathy to his family, who seem to have achieved much of the success which eluded Bill. I am indeed sorry that, by just a few weeks, the family missed the opportunity of celebrating a Golden Wedding anniversary.

Arthur C. Clarke
Colombo
16 July 1989

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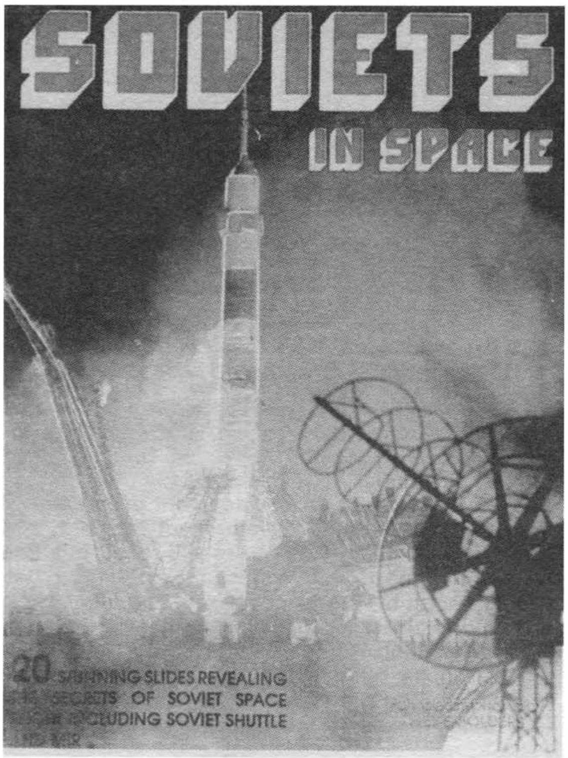

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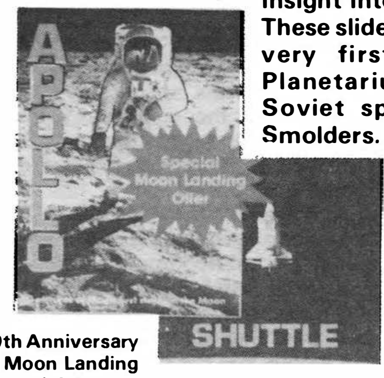

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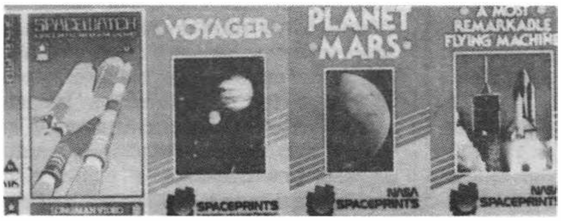

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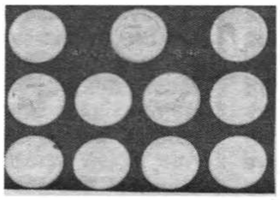

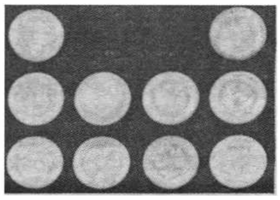

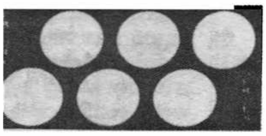

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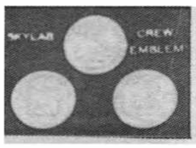

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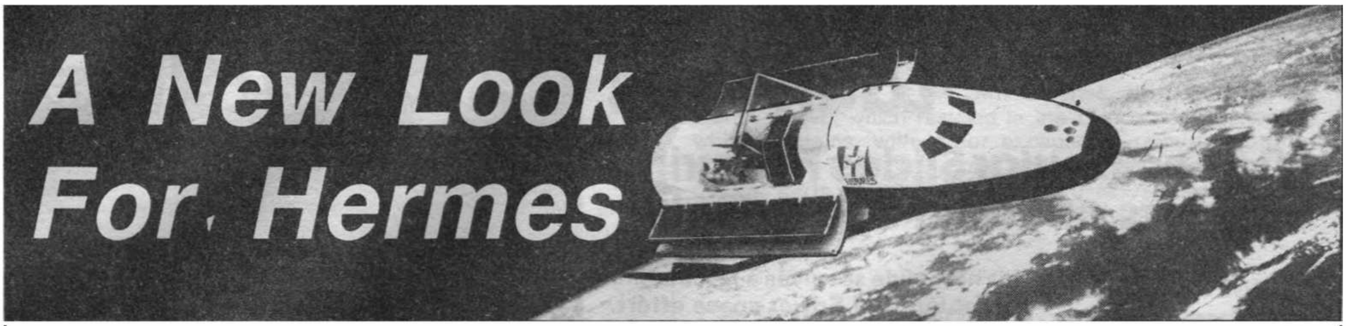
A New Look For Hermes



Hermes' original design, featuring a payload bay and robot arm. *Aerospatiale*

AT the meeting of ESA ministers in Rome in 1985, it was decided that Europe should gradually acquire autonomy in manned space flight. Such autonomy would require the capability to transport men into space and return them to Earth. During the next Council Meeting at ministerial level in November 1987 in the Hague, the Hermes spaceplane was endorsed and the first step in its development programme was approved. In 1988 work began on the Hermes Development Phase 1, which is due to be completed by the end of 1990. This phase will result in a final configuration for Hermes, an estimation of the project's cost and a detailed timetable for further development of the spaceplane. The findings of the Development Phase will be submitted to ESA and permission will be sort to go ahead with Phase 2 in 1991 which would culminate with the first Hermes mission in 1998. But the European spaceplane has undergone dramatic changes since it was first proposed. The new design has met with strong criticism. The question now being asked is are manned capsules an alternative to Hermes?

The original Hermes design had some impressive capabilities: The 17 tonne reusable spaceplane was scheduled to make its first flight in 1995-96. It could carry a payload of 4.5 tonnes in its 35m^3 payload bay and a crew of up to six astronauts. A seven metre long remote controlled arm allowed payloads to be manipulated from the inside the cockpit. A cylindrical airlock, located behind the crew cabin in the payload bay, would have allowed Hermes to dock to the US and European space stations and would also have provided an exit for spacewalking astronauts.

A Hermes mission would begin with a launch atop a new European launch vehicle, the Ariane 5. Despite its name the Ariane 5 uses very little technology developed for the original Ariane series. The vehicle's core stage is powered by a Vulcain HM60 engine fuelled by Liquid Oxygen and Liquid Hydrogen. For the first 126 seconds of flight the core stage is complemented by two Solid Rocket Boosters (SRBs). Following separation from the Ariane 5, Hermes' Orbital Manoeuvring System engines would have boosted the spacecraft into its correct orbit.

After a mission of up to a month (or 90 days if docked to a space station), Hermes would reenter the atmosphere at about Mach 25 and glide to a landing at the Kourou launch site or at Istres, near Marseille, in France. After refurbishment Hermes would be ready for its next mission. The spaceplane was expected to make up to six flights per year.

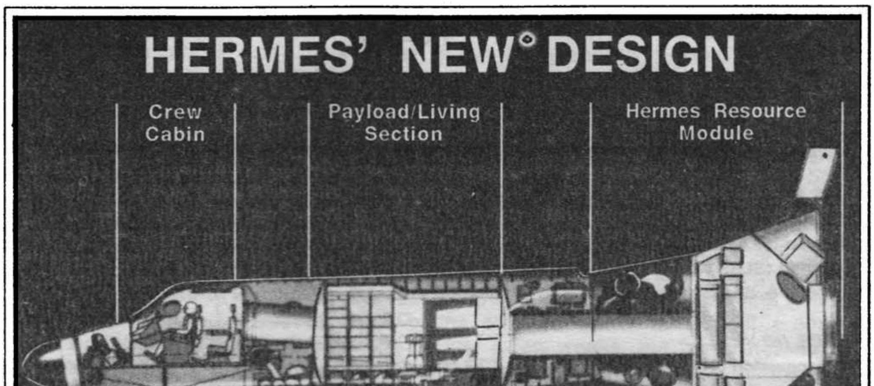
The versatile spaceplane described above has had its wings clipped. Hermes is a shadow of its former self. Gone is the payload bay and the payload bay doors which would have carried cooling radiators. The payload capacity has been reduced to just 3 tonnes. The spaceplane's maximum weight at reentry has been set at 15 tonnes and to keep to this strict limit Hermes can return just 1.5 tonnes of payload and must jettison its propulsion system, airlock and pressurised resource module before reentry.

Hermes' Weight Problem

Hermes' early configurations had a mass of about 17 tonnes and the Ariane 5 was tailored to meet this requirement. But Hermes began to put on weight. Mass estimates for Hermes were continuously revised upwards as development work progressed. But the largest mass increase came after the Challenger disaster when ESA decided Hermes must have a crew escape system. The addition of an ejectable crew cabin added at least 1.5 tonnes to the spaceplane's mass. At one point the spacecraft's launch weight reached 24.4 tonnes. Since then the mass has been whittled down to about 23.9 tonnes.

As Hermes' mass increased it became clear the Ariane 5 would have to be uprated. The propellant load for each SRB was increased from 190 to 230 tonnes. The core stage propellant load was also increased from 140 to 155 tonnes and the thrust of its Vulcain engine uprated by 10% to 110 tonnes. Unfortunately these changes have made the Ariane 5 less suitable for commercial satellite launches. The uprated vehicle can place a satellite of 6.8 tonnes into geostationary transfer orbit but there are few customers with satellites of this size. As a result the Ariane 5 will have to launch three or more satellites at a time. This creates problems matching a suitable trio of satellites for simultaneous launch. Multiple satellite launches worry insurers who feel it is placing too many eggs in one basket.

Hermes' mass continues to be a problem at reentry. To behave as a glider during the landing phase, Hermes must have a wing loading of no more than 190-200 kg/m^2. Wing loading is mass divided by wing area - so the heavier the spaceplane becomes the larger the wings must be. Unfortunately Hermes' wings cannot be increased above the current surface area of about 75 m^2 without placing excessive forces on the Ariane 5 dur-



ing launch. As a result Hermes' reentry mass has been set at a maximum of 15 tonnes.

It was clear Hermes would have to be re-designed.

The New Design

The strategy adopted was: 'take it up but don't bring it back'. Various Hermes components will be jettisoned in orbit to later burn up in the atmosphere, thus reducing the reentry mass.

The spaceplane now consists of four major sections: a crew compartment, a cargo/living area, the Hermes Resource Module (French acronym MRH) and a propulsion module.

The propulsion module carries two engines to boost Hermes into its correct orbit after separating from the Ariane 5 core stage. After completing its burn the propulsion module is jettisoned and burns up in the atmosphere.

The resource module has a volume of 28 m^3 and is capable of fulfilling airlock functions for docking and space walks, as well as accommodating cargo and scientific experiments. The resource module can be outfitted to meet the requirements of specific missions. The MRH will also carry the thermal control radiators. Shortly before reentry the MRH will be jettisoned and will burn up in the atmosphere.

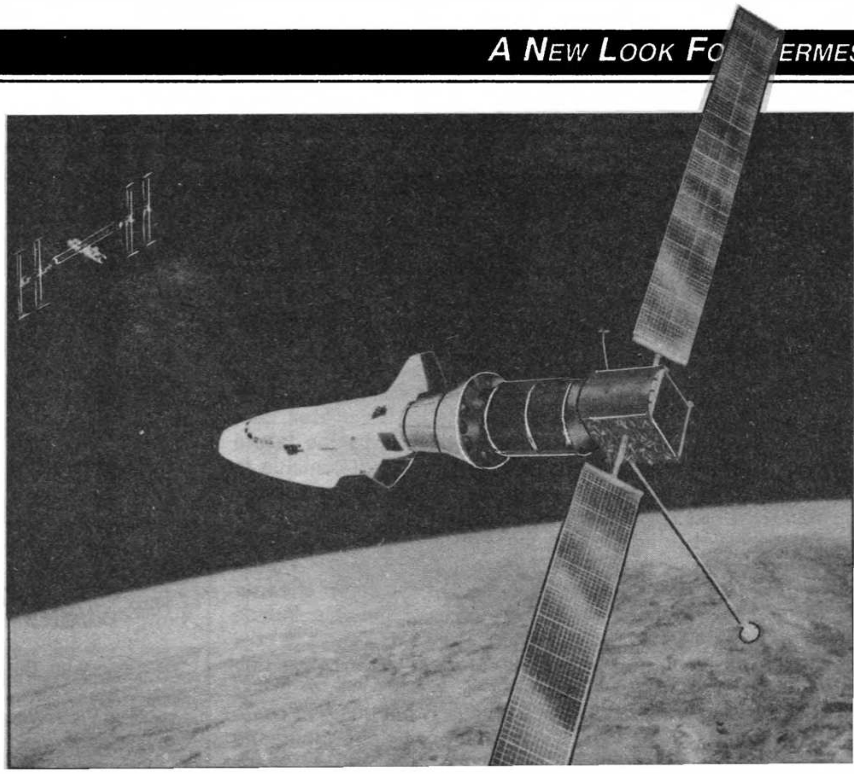
The resource module is linked by a tunnel to a 25 m^3 pressurised compartment which is divided into a payload section and living area for the crew. The latter area will feature facilities for onboard hygiene, food preparation and sleeping. A second tunnel links the compartment with the crew cabin.

The crew compartment is designed so it can be jettisoned if an emergency occurs during launch, although the final method of crew escape is still to be selected. The cabin has three seats for the commander, co-pilot and mission specialist. It seems likely Hermes' cockpit windows will be removed in the final designs. This measure will not only save weight (about 240 kg) but will also allow Hermes to make a more shallow reentry, reducing the heating on the spaceplane's leading edge.

A Critical Reaction

The new Hermes design has met with criticism from many quarters, not least from Reimar Lust, ESA's Director General, who believes the use of expendable components will result in prohibitive operating costs.

Potential Hermes astronauts are reportedly opposed to the escape system. They would rather take the risk of a catastrophe and see the weight saved used in other areas. However in the post-Challenger atmosphere ESA believes it would be unethical not to provide a crew escape system. Martin-Baker is studying an encapsulated ejector seat system for Hermes (see ***Spaceflight,*** December 1988, p.467). The UK firm believes the encapsulated seat would prove the best solution to Hermes' crew escape problem. Its system would have a significant weight saving over an ejectable cabin.



The redesigned Hermes docked to the Columbus free-flying laboratory. *Aerospatiale*

Are Capsules an Alternative?

There is now a strong body of opinion which believes a manned capsule is a serious alternative to Hermes and a cheaper, quicker and a more functional alternative.

Both Aerospatiale and British Aerospace are working on designs for manned capsules.

Two years ago at the British Interplanetary Society's Space '87 exhibition, BAe unveiled their plans for a Multi-Role Capsule (MRC) that could be launched by Ariane 4 in the mid-1990s (***JBIS,*** February 1989, contains full details of the MRC). The capsule could carry a crew of four to an orbiting space station.

But the MRC has a payload capacity of just 250-500 kg compared to Hermes' three tonnes. However studies have indicated even Hermes will probably not meet the cargo requirements of the Columbus Space Station module and Manned Tended Free-Flyer. In light of this ESA has contracted Aerospatiale and BAe to study an unmanned resupply carrier to be launched by Ariane 5. The Ariane Transfer Vehicle (ATV), could transport a logistics module with 7.3 tonnes of cargo including 2-4 tonnes of propellant. So critics of Hermes are suggesting that a manned capsule and ATV could meet Europe's manned space transportation needs. For more than a decade the Soviet Union has successfully operated its space stations using a similar combination of manned capsules and unmanned cargo carriers.

Decision Time

Hermes' final design will be reached this year and ESA will have to make a decision on the project's future in 1990. If Hermes gets a go-ahead the Development Phase 2 will begin in 1991. If all goes to schedule, an Ariane 5 will launch Hermes on an unmanned test flight in 1998 and the following year Hermes will make two manned flights.

If ESA decides Hermes is a costly white elephant what are the prospects for a European manned capsule? BAe, Aerospatiale and Man Technologie have already completed initial studies for Ariane-launched capsules. It would be at least five years before the first manned launch could take place.

The future of the US Freedom Space Station will also influence ESA's future requirements. The latest Freedom re-design will not allow the Manned Tended Free-Flyer to dock with the space station. This makes it even more important for Europe to achieve manned autonomy in space. The question is how? Hermes or manned capsule?

ISSN 038-6340

November 1989 US$3.00 £1.25

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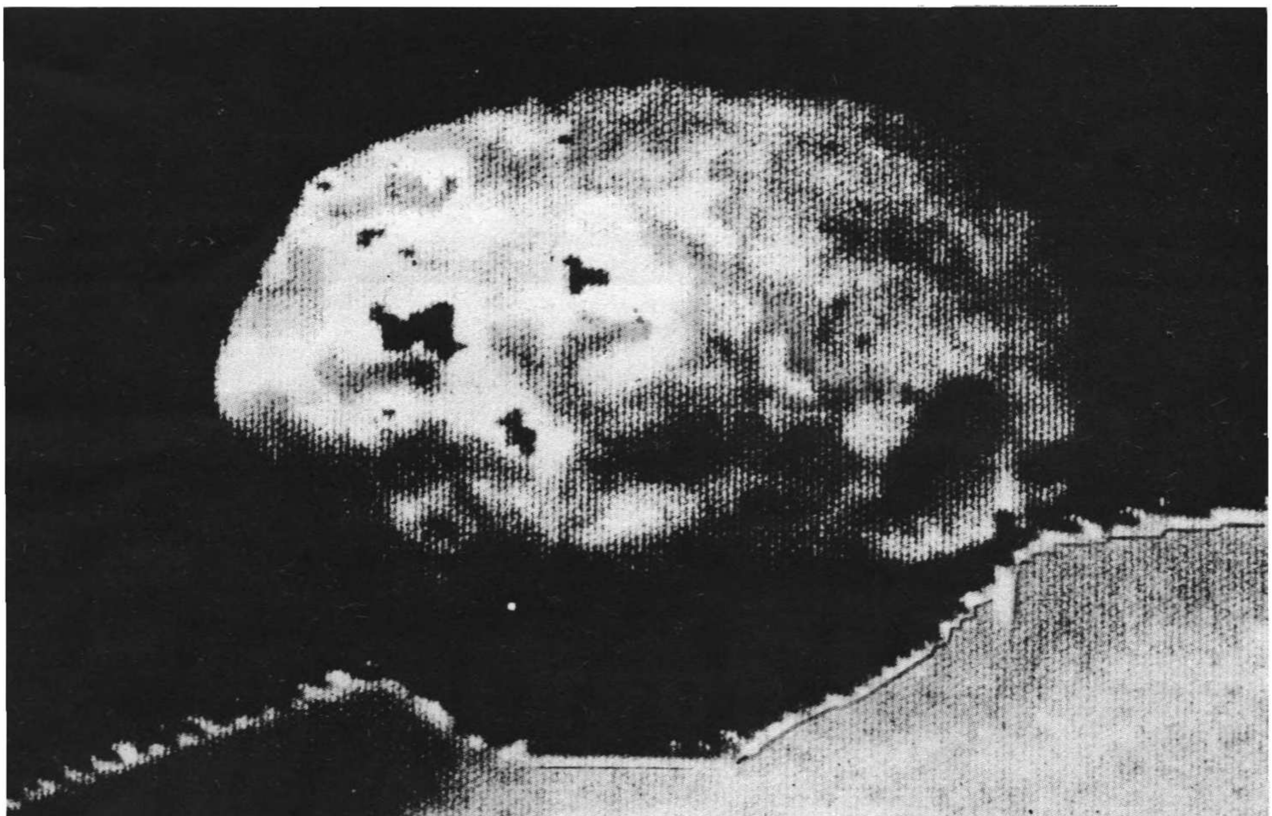

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Published monthly by the British Interplanetary Society Ltd., 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by JWL, Ltd., Aylesbury, Buckinghamshire, England.

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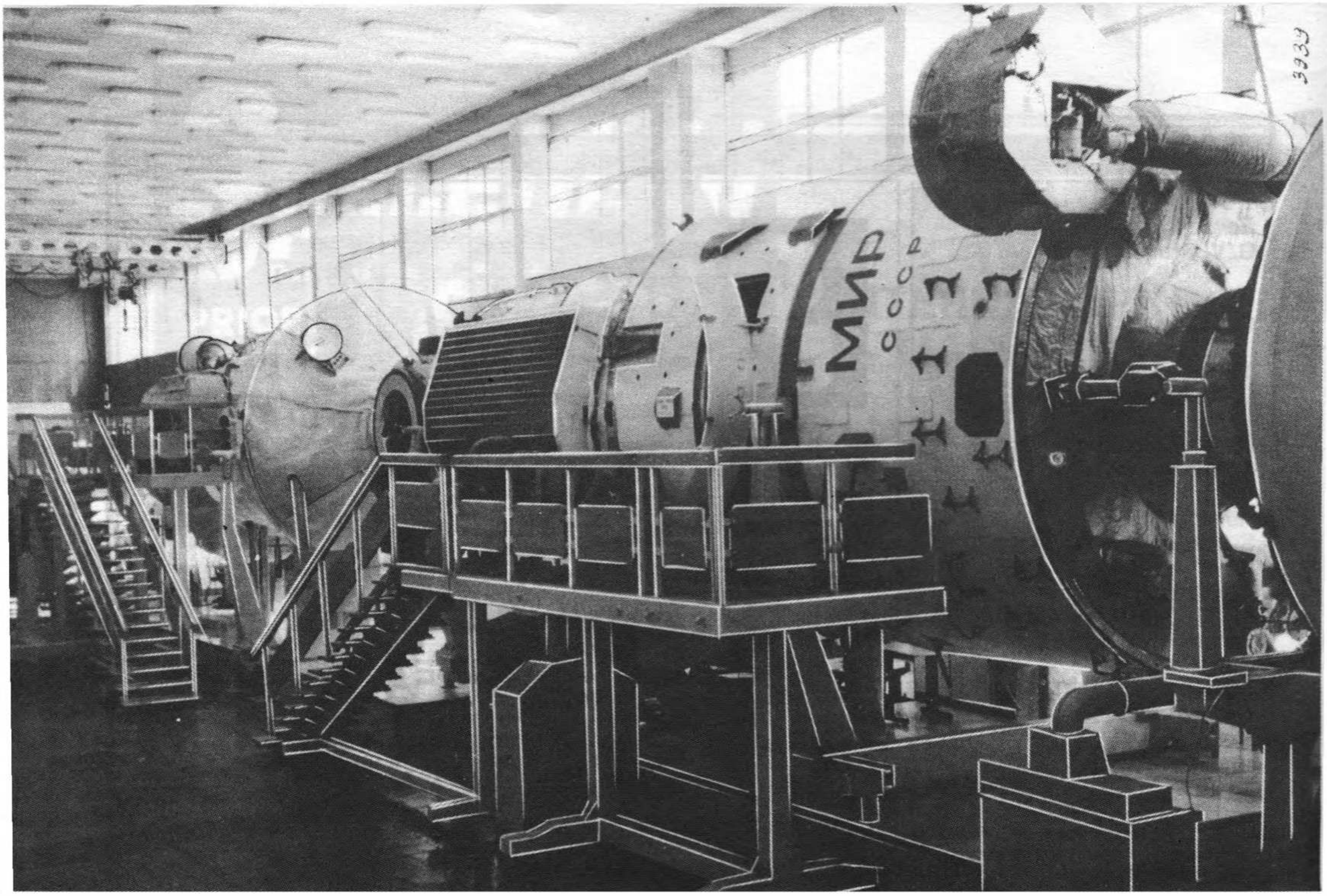
Spaceflight

The International Magazine of Space and Astronautics

Vol. 31 No.11 **November 1989**

FRONT COVER: The Martian moon Phobos seen by the Soviet space probe Phobos-2.
USSR Academy of Sciences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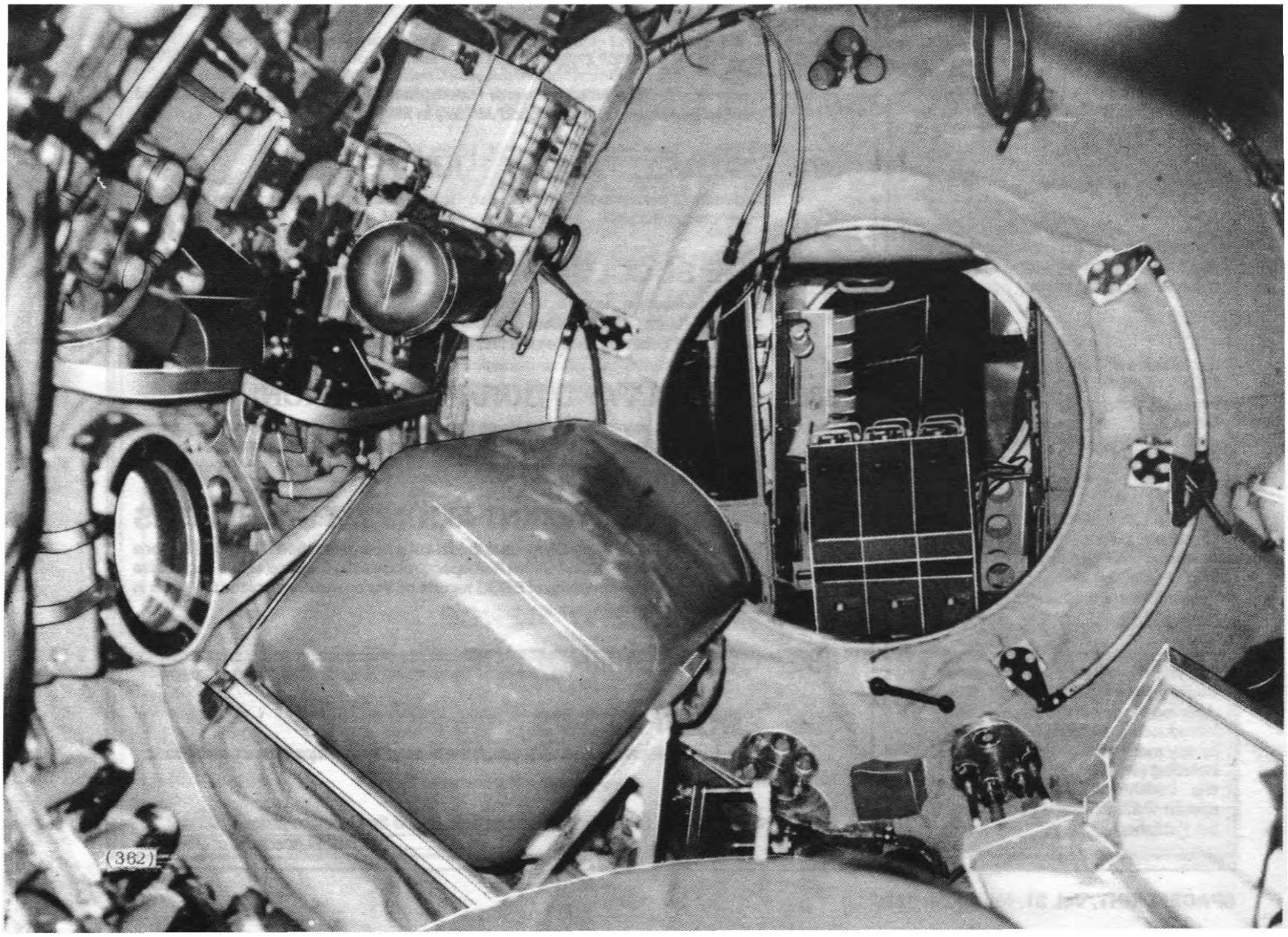
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MIR'S NEW MODULE

Expansion of Mir Begins

The launch of Soyuz TM-8 on September 5 (see *Spaceflight,* October 1989, p.332) was the start of the Soviet Union's plans for the expansion of the Mir space station. The first 20 tonne module was due for launch in October and it will be followed by a second in January 1990.

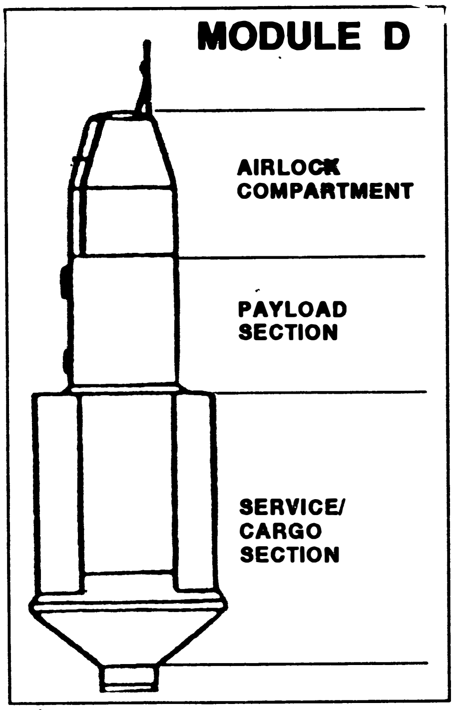
The Mir space station was designed to receive up to five scientific modules. However since its launch on February 20, 1986, the station has received only one small module, the Kvant astrophysical observatory. After months of technical problems the expansion of Mir was about to start as this issue of ***Spaceflight*** went to press.

During September the main task of cosmonauts Serebrov and Viktorenko was to replace Mir's computer memory with an updated version capable of taking into account the additional mass of the new modules as they are docked. The computer needs to know the complex's exact mass in order to manoeuvre the space station.

On September 13 the crew used Progress-M's engines to boost the space station's orbit.

The first of the new modules would 'most likely' be launched on October 16 by a Proton booster, according to Vladimir Solovyov, mission head at the Kaliningrad Flight Control Centre. The Re-equipment Module, also known as Module D, is equipped with a Service module to manoeuvre the 20 tonne structure in orbit. The module will take about a week to approach Mir, using the Kurs guidance system developed for Soyuz TM and Progress M.

Soon after the first module's launch, Progress M-1 was due to undock from Mir's forward port. Then on October 23 Module D is scheduled to dock with the space station. During the docking operation the crew will



seal themselves aboard Soyuz TM-8 as a safety precaution. Once docking has been successfully accomplished a mechanical manipulator arm, known as Ljappa, was to be used to transfer the module to the top radial port (see ***Spaceflight,*** May 1987, p.184-185). The operation will take no longer than 96 min.

On October 25 the two cosmonauts will enter Soyuz TM-8 and separate from the Kvant module. Ground controllers will then rotate the Mir station through 180 degrees and the cosmonauts will redock with Mir's forward axial port. This operation will leave the station's rear docking port vacant for Progress M-2. Scheduled for launch on October 27, the cargo craft will dock with Mir two days later on October 29.

With the module docking operations complete Serebrov and Viktorenko will begin a checkout of the module.

The cosmonauts' busy schedule then calls for five space walks. On the first EVA the crew will transfer a docking mechanism from the top radial port, where the new module has just docked, to the bottom radial port in readiness for the T module. The cosmonauts will not leave the station but the Soviets class the operation as an EVA because it involves depressurising the transfer module so the crew will have to wear EVA suits.

The second EVA will retrieve the French Echantillons experiment attached to the station by Jean-Loup Chretien during his space walk in December 1988. The experiment consists of a rack containing samples to evaluate the behaviour of materials exposed to the environment of space. To retrieve the experiment the cosmonauts will have to disconnect the 50 pin umbilical that connects the rack with a processing unit inside the space station and unhook the springs that attach the experiment to the station's exterior handrails.

During the third EVA the cosmonauts will install two star trackers on the Kvant module. The star trackers will be used by the space station's orientation systems to determine its exact position.

The first tests of the Soviet Union's Cosmonaut Manoeuvring Unit (YMK) are expected in December. The YMK will be delivered to Mir inside the airlock of the Re-equipment module. Aleksandr Serebrov will be tethered at all times during the testing of the YMK. The first YMK space walk will last about five hours and will involve basic tests of the unit's capabilities (see ***Spaceflight,*** September 1989, p.296 for further details). A second EVA with the manoeuvring unit will prove the YMK's abilities for installation and repair work.

With the completion of the EVAs, preparations for the arrival of the second scientific module will begin. Progress M-2 will undock from Mir allowing Soyuz TM-8 to be transferred to the rear (Kvant) docking port on January 28. The Technology Module (also known as Module T) is scheduled to blast off from Baikonur on January 30. On February 6 the module will dock with Mir's forward port and will then be transferred to the lower radial port, opposite the Re-equipment module.

Their mission complete, Viktorenko and Serebrov will be relieved by the crew of Soyuz TM-9, due for launch on February 19. The new crew is expected to be Anatoly Solovyov and Aleksandr Balandin, the back-ups for Soyuz TM-8. Viktorenko and Serebrov will return to Earth in the Soyuz TM-8 capsule on February 19.

Earlier in the year the Soviets' long term plans called for three missions with a five to six month duration, followed by an 18 month record-breaking flight. However the delay in attaching the space station modules may have caused these plans to be revised.

Top: A overall view of the Mir training mock-up with the D Module docked to the space station on the left hand side of the picture. The spheres visible on the exterior of the module contain gyros to control the orientation of the module. Other spheres contain oxygen or water.
Bottom: Taken inside the D Module airlock, the photograph offers a glimpse of the equipment/scientific section. The circular hatch to the service/cargo section is also visible. In future space walks from Mir will be made from this airlock. It will contain the Soviet YMK manoeuvring unit. The large orange block represents the space occupied by a stowed EVA suit. To the left of the space suit mock-up is a porthole. Note the lamps attached to the wall in the equipment/scientific section.

Latest Soviet Biosat Mission

NASA Releases Last Biosat Results

The ninth Soviet Biosat mission got underway on September 15. Designated Cosmos 2044, the satellite carried experiments from NASA and the European Space Agency.

The Biosat is based on the Vostok capsule and was launched by an SL-4, Soyuz booster from the Plesetsk launch site on September 15. The launch was originally scheduled for September 8 but postponed due to technical problems on the spacecraft.

Cosmos 2044's biological specimens were exposed to two weeks of weightlessness. They included Rhesus monkeys, rats, insects, fish and unicellular organisms. The satellite was recovered on September 29.

ESA provided five experiments for the mission and NASA scientists are cooperating in 29 investigations. This is the seventh Soviet Biosat mission to involve US cooperation. Nearly 3,000 biological samples will be returned to NASA for analysis after the mission.

NASA has released the results of an earlier Biosat mission, Cosmos 1887, launched on September 29, 1987. The US experiments aboard the satellite were to investigate the effects of space flight on the major body system, including skeletal bones and muscles, the nervous system, heart, liver, several glands and blood. Special tissue culture studies using pituitary cells studied growth hormone. Spleen and bone marrow cells were used to investigate the effects of microgravity on the immune system. The US also had a radiation measurement system onboard the spacecraft.

NASA says the science results from the Cosmos 1887 experiments were exceptional. In particular, bone studies indicated structural changes in the mineral content. For example, the bending strength of the rat humerus bone was decreased by 40% and the compression strength of the lumbar vertebra decreased by 27%. Muscle studies on the rats showed that while individual muscle weights were similar for both flight and ground control animal groups, the fast muscle types showed significant decrease in cross-sectional area, atrophy and extracellular edema, while at the same time showing increased necrotic fibres and motor end plate degradation. Slow muscle types showed little evidence of atrophy but some biochemical changes. The mitochondria in the heart muscle also showed degeneration and fibre changes. Observations on other body organs and physiological systems were made. They confirmed previous flight research experiments, such as decreased mass and spermatogenesis in the testes; decreased growth hormone release by the anterior pituitary cells; increased cholesterol, triglycerides and organ weight in the liver and a reduced immune response suggested by several types of measure involving the spleen, bone marrow and blood.

NASA is grateful for the opportunity to cooperate with the Soviet Biosat programme. The length of the Cosmos missions is about twice the exposure time in microgravity than in Spacelab flights on the Shuttle. Although NASA will launch its Spacelab Life Sciences mission next year, it will be late 1992 or 1993 before a US mission carries Rhesus monkeys. NASA says the Soviet Biosat missions serve as a testbed for the development of US scientific experiments, technology and flight hardware.

The US has been invited to cooperate in the 1991 Soviet Biosat mission and in return, Soviet scientists have been invited to participate in analysis of specimens from the US Shuttle Spacelab Life Sciences mission currently scheduled for June 1990.

Soviets Open Plesetsk to the West and Admit Space Disasters

In a new display of openness Western journalists visited the world's busiest space centre, the Plesetsk Cosmodrome. During their visit Soviet space officials had to admit two major launch pad disasters after journalists saw a memorial to 50 ground crew killed in the accidents.

Western journalists were taken to the Plesetsk Cosmodrome to observe a satellite launch. The Cosmodrome is located some 500 miles north of Moscow at 62.8 degrees north, 40.1 degrees east, near the city of Mirny. Since the first launch in 1966 over 1,200 satellites, mostly military in nature, have blasted off from Plesetsk.

The recent visit uncovered two major launch pad disasters. A Soviet official told reporters a Soyuz launcher was being fuelled on March 18, 1980 when an explosion tore through the pad killing 50 technicians. A second launch pad disaster occurred on June 26, 1973, killing nine ground crew. The bodies of the dead from both accidents were buried beneath a red granite monument in the main square at Mirny. The monument, topped by a granite rocket, overlooks Lake Plesetskaya.

Columbia Remains On Schedule Despite Dousing

Shuttle processing managers believe they can still meet the December 18 launch date for Columbia on mission STS-32 despite a serious incident in the Orbiter Processing Facility (OPF).

Columbia was returned to the Kennedy Space Center in tip-top condition after her five day mission for the Department of Defense in August. Columbia's Flow Director, Ann Montgomery, was confident Columbia would be ready for the urgent STS-32 mission which will recover the Long Duration Exposure Facility.

However on September 24 the orbiter was drenched by thousands of gallons of water when the OPF fire sprinklers were accidentally activated. The Firex System was apparently triggered during maintenance work on a valve. The water ran for seven to ten minutes before it was shut off.

Fortunately, the orbiter's payload bay doors were closed at the time but water did enter the vehicle through the forward Reaction Control System cavity, wing area and several access doors. No water damage occurred in the crew compartment or avionics bays but several heat resistant blankets that cover the orbiter's exterior will have to be replaced. A few electrical components that had been removed from Columbia were exposed to water.

Initial examinations of the vehicle indicate there will be no effect on the December 18 launch target.

A Fiery End for Solar Max

The Solar Maximum Mission satellite, better known as Solar Max, will reenter the Earth's Atmosphere on November 30, according to the latest estimates.

Increased Solar activity now means Solar Max will burn up in the Earth's atmosphere much earlier than reported in the March 1989 issue of ***Spaceflight***. Scientists had hoped the satellite would remain in orbit until late 1990/early 1991 allowing them to continue observations of the Sun during its period of most intense activity. However, the same Solar activity has led to the expansion of the Earth's atmosphere and increased air resistance on the satellite. Earlier this year scientists were predicting Solar Max would reenter in early 1990 but higher than expected Solar activity has accelerated Solar Max's decay and the satellite is now expected to reenter about November 30.

Solar Max was launched in February 1980. Its mission was to observe the Sun during the last period of increased activity. In December 1980 the satellite suffered electrical problems which were later repaired during Shuttle mission STS 41-C in April 1984. The satellite then continued its work. There were plans to retrieve Solar Max with the Space Shuttle, refurbish it and re-launch it but the plans were shelved after the Challenger accident. It was also impossible to schedule a Shuttle mission to boost Solar Max's orbit.

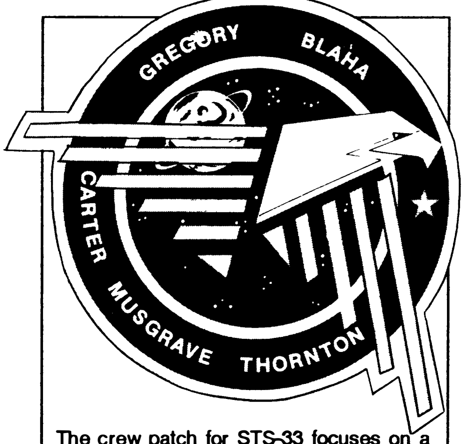
Military Shuttle Set for November 19 Launch

The Space Shuttle Discovery is scheduled to make a dedicated Department of Defense mission on November 19. The mission will launch a classified satellite for the Pentagon.

The military mission, designated STS-33, will be the sixth flight for the orbiter Discovery. Frederick Gregory is Commander for STS-33. John Blaha is the pilot, replacing David Griggs who was tragically killed earlier this year in a plane crash. Mission Specialists are F. Story Musgrave, Kathryn Thornton and Manley Carter. Musgrave and Thornton are the first civilian astronauts to fly on a military shuttle. The mission is expected to last four to five days.

As reported in last month's STS-28 Mission Report, Discovery's payload is believed to be a Magnum electronic intelligence satellite (ELINT). This type of satellite is generally known as a Ferret. Magnum will be deployed from the Shuttle's payload bay about six hours into the mission and will be boosted into geostationary orbit by an Inertial Upper Stage (IUS). From its vantage point about 36,000 km above the Earth, the satellite's powerful listening equipment will be able to monitor military radio transmissions.

3939



The crew patch for STS-33 focuses on a stylized falcon soaring into space. The falcon symbolizes courage, intelligence, tenacity and love of flight, according to the crew. The orbital track represents the falcon's lofty domain. The bold red feathers of the wings were drawn from the American flag. The single gold star on a field of blue honours the memory of the late Rear Adm. S. David Griggs, originally assigned to pilot the mission.

NEWS IN BRIEF

Energia to Fly in 1990

According to reports from the Soviet Union the third Energia will blast off from Baikonur in 1990. The booster has been assembled and is being stored on its transporter in the Energia integration building at Baikonur. A payload for the mission has not yet been selected. Boris Gubanov, Energia chief designer, admitted there was a shortage of payloads for the booster. For the first time Energia's strap-on boosters will be recovered.

More Soviet Shuttle Tests

Igor Volk, leader of the Soviet Shuttle Cosmonaut corps, said orbiter approach and landing tests would resume soon. The tests would use the GLI-Buran (GLI is Russian for Horizontal Flight Test), which is equipped with jet engines for take off. Once sufficient altitude has been gained the jet engines are shut off allowing the cosmonauts to land the orbiter as a glider. The GLI-Buran flew 24 test flights between November 1985 and April 1988.

New Astronauts

NASA has began screening about 2,500 astronaut applications. Successful candidates will join a one year training programme starting in 1990.

NEWS IN BRIEF

Protesters Attempt to Block Galileo Launch

Three anti-nuclear groups took legal action to block the launch of STS-34 carrying the Galileo probe. The protesters objected to the presence of two Radioiostope Thermo-electric Generators (RTGs) aboard the space craft. They claimed a launch accident could contaminate the Florida coast. As this issue of *Spaceflight* went to press, NASA was confident the launch would take place on October 12 despite the legal action. A court hearing was due to be held on October 10. Galileo Lead Flight Director, Milt Heflin, told a press conference: "I am responsible for its [the Galileo payload] safety and I have no qualms about this device. It is an incredibly well put together piece of hardware." The RTGs were installed on Galileo on October 7 and 8.

Ariane Delayed

The launch of Ariane mission V34 has been postponed by about four weeks. The delay was caused by the discovery of faulty electromagnetic relays in the command unit for the Ariane 4 Vehicle Equipment Bays. Ariane was originally scheduled to launch the Intelsat VI (F2) communications satellite on October 5.

50 Fairings for Ariane 4

Arianespace and Contraves signed a contract at the Paris Air Show for production of 50 additional fairings for the Ariane 4 launch vehicle. The contract is valued at 150 million Swiss francs (about $90 million). This order completes the launch vehicle production contract signed on February 15, between Arianespace and its European industrial partners (see *Spaceflight*, April 1989, p.110) The first fairing in this new batch will be delivered in late 1991.

BIS Member Selected for 1991 Shuttle Mission

NASA has selected Claude Nicollier, an ESA astronaut and member of the British Interplanetary Society, as a Mission Specialist for STS-46, scheduled for launch in May 1991.

Claude Nicollier, making his first space flight, will be the first ESA astronaut to fly as a mission specialist. Under a special agreement between NASA and ESA, he was assigned to receive mission specialist training at NASA in 1980.

During the seven day Shuttle flight, the STS-46 crew will deploy the ESA Eureca platform which is a free flying platform designed primarily for microgravity experiments. The platform will be retrieved from orbit 8 months after launch. The crew will also demonstrate the Tethered Satellite System (TSS), designed by Aeritalia for the Italian Space Agency.

Space Station Scaled Down

NASA Administrator, Richard Truly, has submitted a scaled down space station design to the US office of budget management. The new design will enable NASA to meet the 1995 launch date for the first Freedom assembly mission. However the new plans will mean the launch of the European and Japanese modules will be delayed. The space station assembly should be completed by 1999, when NASA will seek additional funds to uprate the station to its original design. The latest re-design will reduce the station's crew to four, compared with a planned crew of eight. The space station will continue to use space shuttle EVA suits instead of a new suit designed for easy on-orbit maintenance.

Atlas Launch Ends Unmanned Era for NASA

The final NASA launch of an unmanned rocket from Cape Canaveral went off without a hitch on September 25th, closing an era for the space agency and opening a new era of commercial space launches.

The Atlas Centaur rocket carrying a Navy communications satellite lifted off from its launch pad at 02.56 EDT. The launch was postponed two years after a pad mishap damaged the fuel tank on what at the time was the last available Centaur upper stage.

The payload, the eighth FLTSATCOM satellite designed to link American armed forces around the world with military leaders and the President, separated from the two-stage rocket about 40 minutes into the flight.

The mission was the 448th unmanned launch for NASA. The agency plans only one more large-scale unmanned launch - a Delta set to lift off November 9th from Vandenberg Air Force Base, California before contracting the business to private aerospace companies.

NASA's move to private unmanned launches is an outgrowth of the "Space Policy and Commercial Space Initiative to Begin the Next Century" introduced by Former President Ronald Reagan.

The Atlas will continue to be used as a commercial launch vehicle by its manufacturer, General Dynamics.

Amroc's First Launch Fails

The first commercially developed launch vehicle was destroyed on its first launch attempt from Vandenberg Air Force Base on October 5. Soon after ignition at 10:28 PDT the vehicle was engulfed in flames. The rocket was to carry experiments from the US Air Force and Massachusetts Institute of Technology on a sub-orbital flight. Both payloads were destroyed in the accident. The American Rocket company blames the failure of the launch on a faulty oxygen valve.

Hipparcos Begins Work

The ESA astronomy satellite, Hipparcos, has begun work in its transfer orbit after its apogee boost motor failed to fire (see *Spaceflight*, October 1989, p.329). The spacecraft's perigee was increased to 500 km between September 7-11. On September 12 the three solar panels and the 'fill-in' antenna were successfully deployed. On September 22 the transition from spin stabilisation to three-axis control was completed. The two telescope aperture baffles were opened on September 26 and following a test of the satellite's detectors, work commenced.

Go-Ahead for Spot-4

The French government has given the go-ahead for the fourth Spot Earth resources satellite. This will ensure that the Spot series will continue operating until the year 2000.

Spot-1 was launched on February 22 1986 and is to be followed by Spot-2, scheduled for launch in November and Spot-3, which is expected to be launched in 1992. The new Spot-4 satellite will be ready in 1994 and will be launched by Ariane 4 at the end of Spot-3's service life.

The new satellite has an increased lifetime of five years. The Spot instrumentation has been improved for the fourth satellite. It will be capable of analyzing the landscape at an additional wavelength located in the infrared, which is more suitable for the analysis of plant life. Colour images with a ten metre resolution will be obtained more easily than with the present system. Some of the improved Spot technology will be used for the Helios military surveillance satellite.

GE Astro Space and Marconi Space Systems Working Together on Inmarsat-3

GE Astro-Space Division of the USA and Marconi Space Systems of Britain are combining resources in bidding Inmarsat's Third Generation Space Segment (Inmarsat-3). This next generation of satellites will consist of a minimum of three satellites with options for up to nine spacecraft.

Under this agreement, GE Astro Space will assume the role of prime contractor and provide for the integration and test of the communications payload of transponders and antennas to be provided by Marconi Space Systems.

The Marecs A and B spacecraft, vital links in Inmarsat's current worldwide communications network, include communications payloads designed and manufactured by Marconi Space Systems. Recently, under ESA contract, Marconi has developed an advanced communications payload designated ARAMIS which is specifically designed for mobile land, sea and airborne end-users.

Search for British Astronaut Reaches Final Stages

The search for Britain's first astronaut has entered its final stages. Following the gruelling medical examinations described in last month's *Spaceflight,* the number of candidates was reduced to 16. The remaining would-be astronauts were then subjected to extensive testing at the RAF's Institute of Aviation Medicine (IAM).

During the week beginning October 9, the 16 candidates were subjected a dynamic test programme at the IAM, Farnborough. The exercises were designed to test their ability to withstand high g-forces, lack of oxygen, disorientation and other stresses associated with space flight. The tests are based on the Soviet requirements for a career cosmonaut.

The Institute's human centrifuge simulated the g-forces the British astronaut will experience during launch and reentry. The candidates were subjected to 8g from front to back, making it difficult to breathe and 5g from head to foot which forces the blood to the legs. The IAM's human centrifuge is the only one of its kind in the UK. It weighs 42 tons and has two cabins at either end of its 30 ft arms.

The IAM's altitude chamber was used to simulate the low oxygen pressure at an altitude of 5,000 m, Sq. Ldr. David Gradwell explained. The candidates sat in the chamber for about 30 minutes and were asked to carry out mental tasks, such as reading or arithmetic. During the tests the candidate's blood pressure and heart rate were monitored and a mass spectrometer analyzed each breath exhaled to assess how well their bodies take up the available oxygen. The altitude chamber then simulated a rapid descent to ground level to check the candidates could clear their ears.

The Juno candidates were tested for their susceptibility to motion sickness. However, Dr Rollin Stott, Medical Officer at IAM, admitted it was difficult to anticipate how candidates might be affected by space sickness once in orbit.

The first test involved running the candidates backwards and forwards on a track every five seconds for a period of up to 20 minutes. During each oscillation the candidate experienced from +0.4 to -0.4 of normal Earth gravity.

For the second motion sickness test the candidates were blindfolded and rotated in a chair at speeds of up to one rotation every two seconds. They started with their head on a rest at waist height. After 20 seconds of spinning they had to bring themselves upright and then return to the bent forward position. They had to repeat this procedure for a minute. The chair was then rotated in the opposite direction and the whole test was repeated a total of 12 times.

Three separate exercises tested the candidates' vestibular systems (the body's balance mechanism). For the first test they were seated in the dark on a chair which oscillates from side to side. Electrodes measured eye movement during these tests. During the procedure the candidates were asked to solve mental arithmetic problems.

The next test, also in darkness, involved the candidates being rotated at a constant speed for a minute, atfter which the chair was suddenly halted and the eye movements induced recorded. The doctors were particularly interested in the candidates' speed of recovery after this test.

The third test was to check the candidates' have normal balance function in both ears. Hot water was syringed into each ear setting off movements in the fluid of the semi-circular canals of the inner ear. This induces eye movements which were recorded and analyzed.

In the IAM's Climatic Chamber the candidates' blood flow was tested. Infrared pictures of the head and hands were recorded as the temperature in the chamber was varied.

The 16 Juno Candidates

Gordon Brooks	George Loizou
Karen Carr	Timothy Mace
Patrick Collins	Grant Mason
William Curtis	David Owens
Andrew Dennis	Helen Sharman
Robert Eden	Clive Smith
David Eyley	Richard Stone
Adrian Jackson	Roger Turner

Two members of the British Interplanetary Society remain in the race to become Britain's first astronaut. They are David Eyley and David Owens.

Apologies to David Owens, a pilot with British Midland Airways and a BIS member since 1987, who was accidentally omited from last month's listing of BIS members to reach the 24 candidate stage.

Two Juno candidates were at the British Interplanetary Society's Headquarters in London for a photocall. They were Clive Smith (left) and Chris Welch. Unfortunately Chris did not reach the shortlist of 16. Both work at Kingston Polytechnic. *Kingston Polytechnic*

After returning to Earth astronauts' blood tends to be displaced to the legs. To simulate these conditions an air tight compartment wwas used to create negative pressure around the lower part of the body, causing blood to be displaced to the legs. In another test the candidates were tilted from a relaxed horizontal position to nearly upright. Again this causes blood to pool in the legs. In both tests the candidates' blood pressure and heart rate were recorded.

Only a handful of candidates are expected to fail the dynamic test programme according to Juno Medical Director, Peter Howard. "I reckon we will get 10 or 12 out with a clean bill of health", he told ***Spaceflight.*** Each remaining candidate will be interviewed by a panel and eight will be selected to travel to Moscow on November 12. The Soviets will then produce a list of four from which the Juno project will select the final two: a prime candidate and a back-up. The announcement of the final two will be made in late November.

Meanwhile, work continues to raise sponsorship for the £16 million mission. Mission Director, Peter Graham, told ***Spaceflight*** £3.9 million had been raised by early October and he remained confident of raising the remaining funds.

It seems likely an ITV team will win the exclusive television rights to the Juno mission. The television companies will be able to follow the British astronaut throughout the training period and the mission itself.

SATELLITE DIGEST-223

This month sees a new look for *Spaceflight's* regular feature, Satellite Digest. In order to present the very latest satellite launches, in a concise form, Satellite Digest will be produced in two sections. Orbital Data is in the form of a table which lists each satellite's name, international designation, launch time and date, launch site, launch vehicle, perigee, apogee, period and inclination. Launch times are approximate, except when marked with an asterisk, when the time given is that issued by the launching agency. All times are GMT. Soviet launch vehicles have been named by the Sheldon system of classification. Orbital data has been provided by the Royal Aerospace Establishment. The first section, Satellite Data, contains notes on each satellite's mission.

COSMOS 1986 (1988-116A): Manoeuvrable military photo reconnaissance satellite, with return capsules for film. Reentered on February 11, 1989.
COSMOS 1987 & 1988 (1989-01A & 01B): A pair of navigation satellites. Part of the GLONASS system. Launched with Cosmos 1989.
COSMOS 1989 (1989-01C): A spherical passive geodetic satellite known as Etalon. Launched with Cosmos 1987 & 1988.
COSMOS 1990 (1989-02A): Earth resources photo satellite. Recovered on February 11.
COSMOS 1991 (1989-03A): Military photo reconnaissance satellite. Recovered on February 1.
GORIZONT 17 (1989-04A): Geostationary communications satellite. Stationed at 53 degrees east.
COSMOS 1992 (1989-05A): Communications satellite.
INTELSAT 5A F-15 (1989-06A): Communications satellite.
COSMOS 1993 (1989-07A): A manoeuvrable photo reconnaissance satellite. Reentered on March 27.

SATELLITE DATA

PROGRESS 40 (1989-08A): Carried cargo to the Mir space station. Docked with the rear (Kvant) port at 1030, February 12, 1989. Remained docked to the space station until 0146, March 3. Shortly after undocking, two large-sized, multi-link folded structures on the side of Progress 40 unfurled one after the other. The Mir crew took still and video pictures of the deployment of the structure. At 0108, March 5, Progress 40 was deorbited and destroyed during reentry.
COSMOS 1994, 1995, 1996, 1997, 1998, 1999 (1989-09A - F): Six satellites launched simultaneously. Exact mission unknown.
COSMOS 2000 (1989-10A): Earth resources photo satellite. Its mission included mapping the central areas of Antarctica. It will provide data on the ice cover, on the outcrops of rocks and the formation of glaciers and icebergs. Recovered March 3.
COSMOS 2001 (1989-11A): An early warning satellite.
COSMOS 2002 (1989-12A): A military satellite? Exact mission unknown. Ten objects separated from the satellite during February.
NAVSTAR 2-01 (1989-13A): First of a new generation of navigation satellite. Part of the Global Positioning System (GPS).
MOLNIYA 1-75 (1898-14A): Communications satellite.
COSMOS 2003 (1989-15A): Military photo reconnaissance satellite of the Vostok type. Recovered on March 3, 1989.
AKEBONO (1989-16A): Named Exos-D before launch. Akebono means dawn. Designed to study aurora.
COSMOS 2004 (1989-17A): Navigation satellite.
METEOR 2-18 (1989-18A): Weather satellite.
COSMOS 2005 (1989-19A): Manoeuvrable photo reconnaissance satellite. Recovered on April 25.
JCSAT 1 (1989-20A): A Hughes HS 393 communications satellite operated by the Japanese Communications Satellite Company. Stationed at 150 degrees east.
METEORSAT 4 (1989-20b): Known as

ORBITAL DATA

Name & International Designation	Launch Time and Date	Launch Site	Launch Vehicle	Perigee	Apogee	Period	Inclin.
COSMOS 1986, 1988-116A	1000, 29 December	Baikonur, USSR	SL-4	212	261	89.24	64.78
		1989 LAUNCHES					
COSMOS 1987, 1989-01A	2006, 10 January	Baikonur, USSR	SL-12	19,135	19,194	677.11	64.86
COSMOS 1988, 1989-01B				19,140	19,380	680.89	64.88
COSMOS 1989, 1989-01C				25,504	19,102	675.57	64.87
COSMOS 1990, 1989-02A	1131, 12 January	Plesetsk, USSR	SL-4	256	269	89.91	82.57
COSMOS 1991, 1989-03A	0824, 18 January	Baikonur, USSR	SL-4	207	376	90.37	69.97
GORIZONT 17, 1989-04A	0921, 26 January	Baikonur, USSR	SL-12	35,776	35,803	1,436.14	1.49
COSMOS 1992, 1989-05A	1536, 26 January	Plesetsk, USSR	SL-8	772	808	100.70	74.05
INTELSAT 5A F-15, 1989-06A	0121*, 27 January	Kourou, French Guiana	Ariane 2 (V28)	35,755	35,755	1,435.98	8.41
COSMOS 1993, 1989-07A	1229, 28 January	Baikonur, USSR	SL-4	170	350	89.71	64.76
PROGRESS 40, 1989-08A	0854*, 10 February	Baikonur, USSR	SL-4	186	234	88.63	51.63
COSMOS 1994, 1989-09A	1522, 10 February	Plesetsk, USSR	SL-14	1,397	1,416	113.98	82.62
COSMOS 1995, 1989-09B				1,413	1,418	114.18	82.62
COSMOS 1996, 1989-09C				1,407	1,417	114.11	82.61
COSMOS 1997, 1989-09D				1,401	1,417	114.04	82.62
COSMOS 1998, 1989-09E				1,391	1,417	113.93	82.61
COSMOS 1999, 1989-09F				1,385	1,417	113.86	82.62
COSMOS 2000, 1989-10A	1702, 10 February	Plesetsk, USSR	SL-4	341	390	91.91	82.36
COSMOS 2001, 1989-11A	0419, 14 February	Plesetsk, USSR	SL-6	624	39,727	717.70	62.84
COSMOS 2002, 1989-12A	1709, 14 February	Plesetsk, USSR	Unknown	185	2,293	110.27	65.85
NAVSTAR 2-01, 1989-13A	1829*, 14 February	Pad 17A CCAFS, USA	Delta-2 (184)	19,860	20,270	713.20	55.11
MOLNIYA 1-75, 1989-14A	1102, 15 February	Baikonur, USSR	SL-6	462	39,897	717.68	62.94
COSMOS 2003, 1989-15A	1453, 17 February	Plesetsk, USSR	SL-4	233	267	89.50	62.81
AKEBONO, 1989-16A	2331, 21 February	Tanegashima, Japan	M-3S-2	277	10,460	211.23	75.11
COSMOS 2004, 1989-17A	0336, 22 February	Plesetsk, USSR	SL-8	972	1,018	105.07	82.92
METEOR 2-18, 1989-18A	0405, 28 February	Plesetsk, USSR	SL-14	941	960	104.12	82.52
COSMOS 2005, 1989-19A	1858, 2 March	Plesetsk, USSR	SL-4	189	326	89.65	62.80
JCSAT 1, 1989-20A	2329*, 6 March	Kourou, French Guiana	Ariane 44LP (V29)	35,686	35,873	1,435.63	0.11

MOP-1 before launch. ESA's first operational meteorological satellite. Stationed in geostationary orbit at 0 degrees.

STS-29 (1989-21A): Onboard Discovery were astronauts Michael Coats, John Blaha, James Buchli, Robert Springer and James Bagian. Discovery deployed TDRS-4 (see below). After 4 days 23 hours 40 seconds, Discovery touched down at Edwards AFB at 1436, March 18, 1989.

TDRS-4 (1989-21B): Deployed from Discovery at 2110 on March 13, 1989. Boosted into Geostationary orbit by IUS-19 (Inertial Upper Stage). Stationed at 41 degrees west.

COSMOS 2006 (1989-22A): Military photo reconnaissance satellite of the Vostok type. Recovered on March 30.

PROGRESS 41 (1989-23A): Carried supplies to the Mir space station. Docked with rear (Kvant) port at 2051, March 18. On April 10 Progress 41 was used to boost Mir's orbit to a 400 x 372 km storage orbit. At 0146, April 21 Progress 41 undocked. Progress 41's deorbit manoeuvre failed (probably because it ran out of fuel) and it decayed naturally, reentering at 1202, April 25.

COSMOS 2007 (1989-24A): Military reconnaissance satellite.

COSMOS 2008, 2009, 2010, 2011, 2012, 2013, 2014 & 2015 (1989-25A - H): Eight communications satellites launched simultaneously. Believed to be spherical in shape.

USA 36 (1989-26A): An SDI experiment known as Delta Star. The second stage of the Delta launch vehicle was used as a target for rocket plume detecting sensors aboard the satellite.

TELE-X (1989-27A): Business communication and direct broadcast TV satellite for Nordiska Satellitaktiebolaget (Nordic Satellite Company).

COSMOS 2016 (1989-28A): Navigation satellite.

COSMOS 2017 (1989-29A): A manoeuvrable photo reconnaissance satellite of the Vostok type. Recovered on April 19.

RADUGA 23 (1989-30A): Communications satellite in geostationary orbit. Part of the Orbita-2 network.

COSMOS 2018 (1989-31A): Manoeuvrable photo reconnaissance satellite.

PHOTON 2 (1989-32A): A microgravity material processing satellite based on the Vostok capsule.

STS-30 (1989-33A): The Space Shuttle Atlantis deployed the Magellan probe to Venus. Onboard Atlantis for the four day mission were astronauts Walker, Grabe, Lee, Thagard and Cleave. Atlantis landed at Edwards AFB at 1943:33 on May 8.

MAGELLAN (1989-33B): A probe to accurately map the surface of the planet Venus, currently enroute. Deployed from Atlantis' payload bay at T+6 hrs 14 mins 29 secs.

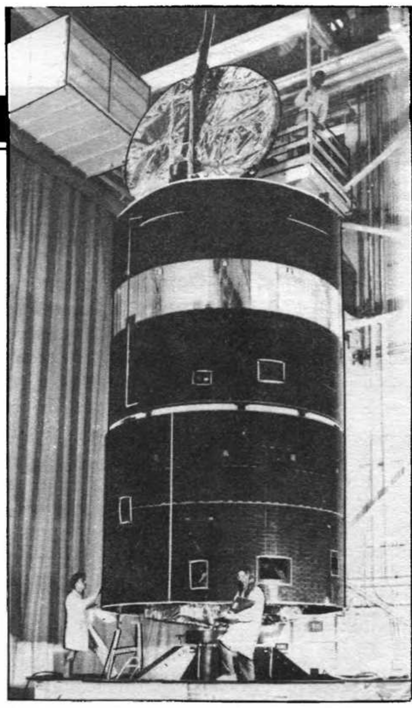
COSMOS 2019 (1989-34A): Photo reconnaissance satellite based on the Vostok capsule. Recovered on May 18.

USA 37 1989-35A): ELINT satellite codenamed Chalet.

COSMOS 2020 (1989-36A): A manoeuvrable photo reconnaissance satellite.

COSMOS 2021 (1989-37A): Photo reconnaissance satellite. Recovered July 6.

RESURS-F 1 (1989-38A): Manoeuvrable earth resources photography satellite based on the Vostok capsule and of the same design as the USSR's military photo reconnaissance satellites e.g. Cosmos 2019. Recovered on June 17.



JCSAT 1 (1989-20A) during pre-launch preparations. Note technicians for scale

PION 1 (1989-38C): Separated from Resurs-F 1 on June 8 at about 1900. A passive satellite constructed by the students of the Korolev Aviation Institute, Kuibyshev.

PION 2 (1989-38D): Separated from Resurs-F 1 on June 9 at about 2200. See Pion 1 for details.

UPDATES

OFFEQ-1 (1988-87A): Israel's first satellite reentered on January 14, 1989 after 117 days in orbit.

ORBITAL DATA

Name & International Designation	Launch Time and Date	Launch Site	Launch Vehicle	Perigee	Apogee	Period	Inclin.
METEORSAT 4, 1989-20B				35,537	35,888	1432.21	1.17
STS-29, 1989-21A	1457*, 13 March	Pad 39B, KSC, USA	Discovery	301	332	90.67	28.46
TDRS-4, 1989-21B	1457*, 13 March	Pad 39B, KSC, USA	Discovery	35,652	35,831	1,433.70	0.16
COSMOS 2006, 1989-22A	1453, 16 March	Plesetsk, USSR	SL-4	244	380	90.75	62.84
PROGRESS 41, 1989-23A	1854*, 16 March	Baikonur, USSR	SL-4	276	373	90.96	51.64
COSMOS 2007, 1989-24A	1229, 23 March	Baikonur, USSR	SL-11	230	285	89.67	64.73
COSMOS 2008, 1989-25A	1341, 24 March	Plesetsk, USSR	SL-8	1,394	1,471	114.54	74.01
COSMOS 2009, 1989-25B				1,409	1,472	114.71	74.01
COSMOS 2010, 1989-25C				1,425	1,472	114.88	74.01
COSMOS 2011, 1989-25D				1,440	1,472	115.06	74.01
COSMOS 2012, 1989-25E				1,457	1,472	115.24	74.01
COSMOS 2013, 1989-25F				1,466	1,481	115.43	74.01
COSMOS 2014, 1989-25G				1,471	1,491	115.60	74.01
COSMOS 2015, 1989-25H				1,470	1,511	115.81	74.01
USA-36, 1989-26A	2151, 24 March	Pad 17 CCAFS, USA	Delta-183	482	504	94.39	47.69
TELE-X, 1989-27A	0228*, 2 April	Kourou, French Guiana	Ariane 2	35,770	35,804	1,436.00	0.10
COSMOS 2016, 1989-28A	1843, 4 April	Plesetsk, USSR	SL-8	957	1,014	104.87	82.96
COSMOS 2017, 1989-29A	1355, 6 April	Plesetsk, USSR	SL-4	231	299	89.80	62.81
RADUGA 23, 1989-30A	0405, 14 April	Baikonur, USSR	SL-12	36,491	36,615	1,473.92	1.43
COSMOS 2018, 1989-31A	1829, 20 April	Plesetsk, USSR	SL-4	188	350	89.89	62.81
PHOTON 2, 1989-32A	1702, 26 April	Plesetsk, USSR	SL-4	216	380	90.48	62.82
STS-30, 1989-33A	1847, 4 May	39B KSC, USA	Atlantis	295	303	90.31	28.89
MAGELLAN, 1989-33B				HELIOCENTRIC ORBIT			
COSMOS 2019, 1989-34A	1258, 5 May	Plesetsk, USSR	SL-4	190	354	89.94	62.86
USA 37, 1989-35A	1947, 10 May	CCAFS, USA	Titan 34D	GEOSTATIONARY ORBIT			
COSMOS 2020, 1989-36A	1258, 17 May	Baikonur, USSR	SL-4	172	341	89.65	64.78
COSMOS 2021, 1989-37A	1034, 24 May	Baikonur, USSR	SL-4	213	277	89.43	69.95
RESURS-F 1, 1989-38A	0853, 25 May	Plesetsk, USSR	SL-4	255	272	89.83	82.30
PION 1, 1989-38C				256	268	89.81	82.29
PION 2, 1989-38D				257	268	89.82	82.30

Galileo Targets Jupiter

ON October 12 the Space Shuttle Atlantis was due to blast off from Pad 39B at the Kennedy Space Center carrying the Galileo Jupiter probe. About six hours 21 minutes into the flight the probe was to have been deployed from the Shuttle's payload bay atop an IUS booster. In this article we take a look at the eight year mission to explore Jupiter. The Galileo probe is designed to study the planet's atmosphere, satellites and surrounding magnetosphere. It was named for the Italian Renaissance scientist who discovered Jupiter's major moons with the first astronomical telescope. This mission will be the first to make direct measurements from an instrumented probe within Jupiter's atmosphere and the first to conduct long-term observations of the planet and its magnetosphere and satellites from orbit around Jupiter. It will be the first orbiter and atmospheric probe for any of the outer planets. On the way to Jupiter, Galileo will also observe Venus, the Earth-Moon system, one or two asteroids and various phenomena in interplanetary space.

After leaving Earth orbit, Galileo will fly past Venus, and twice by the Earth, using gravity assists from the planets to pick up enough speed to reach Jupiter. Travel time from launch to Jupiter is a little more than six years.

In December 1995 the Galileo atmospheric probe will conduct a brief direct examination of Jupiter's gigantic atmosphere, while the larger part of the craft, the orbiter, begins a 22-month, 10-orbit tour of the major satellites and the magnetosphere, including long-term observations of Jupiter throughout this phase.

The 2,400 kg Galileo orbiter spacecraft carries 10 scientific instruments; there are another six on the 340 kg probe. The spacecraft radio link to Earth serves as an instrument for additional scientific measurements. The probe's scientific data will be relayed to Earth by the orbiter during the 75-minute period while the probe is descending into Jupiter's atmosphere.

Galileo will communicate with its controllers and scientists through the Deep Space Network, using tracking station in California, Spain and Australia.

Earth to Jupiter

The Galileo mission was previously designed for a direct flight of about two and a half years to Jupiter. Changes in the launch system after the Challenger accident, including replacement of the Centaur upper-stage rocket with the IUS, precluded this shorter flight. Trajectory engineers designed a new interplanetary flight path using gravity assists, once with Venus and twice with Earth, to build up the speed to reach Jupiter, taking a total of just over six years. This is called the Venus-Earth-Earth-Gravity-Assist or VEEGA trajectory.

Galileo will make three planetary encounters in the course of its gravity-assisted flight to Jupiter.

These provide opportunities for scientific observation and measurement of Venus and the Earth-Moon system. The mission also has a chance to fly close to one or two asteroids, bodies which have never been observed close up, and obtain data on other phenomena of interplanetary space.

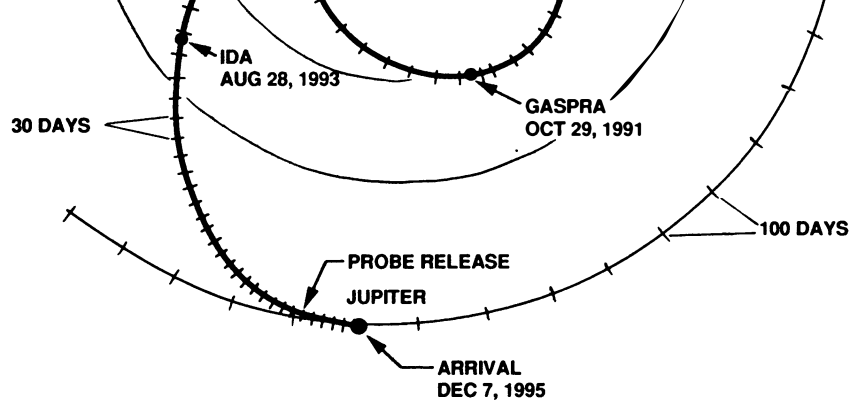
Scientists are presently studying how to use the Galileo scientific measurements and the limited ability to collect, store and transmit data during the early phase of flight to make the best use of these opportunities. Instruments designed to observe Jupiter's atmosphere from afar can improve our knowledge of the atmosphere of Venus; sensors designed for the study of Jupiter's moons can add to our information about our own Moon.

Venus - The Galileo spacecraft will approach Venus early in 1990 from the night side and pass across the sunlit hemisphere, allowing observation of the clouds and atmosphere. Both infrared and ultraviolet spectral observations are planned, as well as several camera images and other remote measurements.

The search for deep cloud patterns and possibly also for lightning storms will be limited by the fact that all the Venus data must be tape-recorded on the spacecraft for playback eight months later.

The spacecraft was originally designed to operate between Earth and Jupiter, where sunlight is 25 times weaker than at Earth and temperatures are much lower. The VEEGA mission will expose the spacecraft to a hotter environment from Earth to

GALILEO'S VEEGA FLIGHT PATH



Venus and back; spacecraft engineers devised a set of sunshades to protect the craft. For this system to work, the front end of the spacecraft must be aimed precisely at the Sun, with the main antenna furled for protection from the Sun's rays until after the first Earth flyby in December 1990. Therefore, scientists must wait until the spacecraft is close to Earth to receive the recorded Venus data, transmitted through a low-gain antenna.

Earth (First Pass) - Approaching for the first time about 14 months after launch, the Galileo spacecraft will observe from a distance the nightside of Earth and parts of both the dark and bright sides of the Moon. After passing Earth, Galileo will observe its sunlit side. At this short range, scientific data are transmitted at the high rate using only the spacecraft's low-gain antennae. The high-gain antenna is to be unfurled like an umbrella and its high-power transmitter turned on and checked out, about five months after the first Earth encounter.

First Asteroid - Nine months after the Earth passage, Galileo will enter the asteroid belt and two months later will have its first asteroid encounter. Gaspra is believed to be a fairly representative main-belt asteroid, about 10 miles or 15 kilometres across and probably similar in composition to stony meteorites.

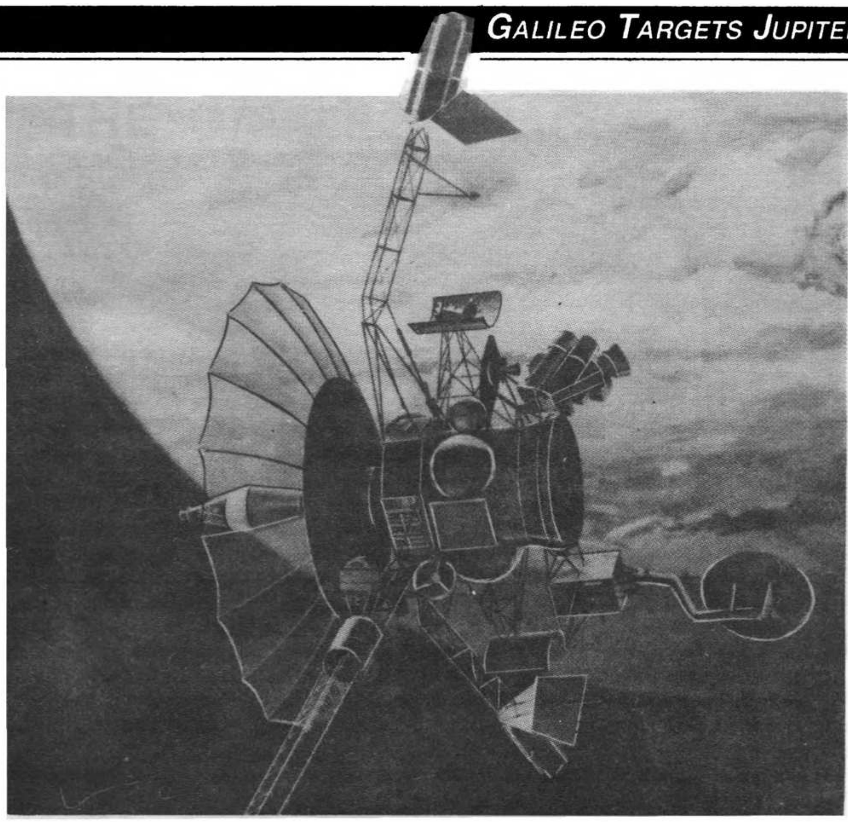
The spacecraft will pass within about 1,000 km at a relative speed of about 29,000 km per hour; it will collect several pictures of Gaspra, and measurements to indicate composition and physical properties.

Earth (Second Pass) - Thirteen months after the Gaspra encounter, the spacecraft will have completed its two-year elliptical orbit around the Sun and will arrive back at Earth. It will need a much larger ellipse (with a six-year period) to reach as far as Jupiter and the second flyby of Earth will pump the orbit up to that size.

Passing about 300 km above the surface, near the altitude at which it had been deployed from the Space Shuttle almost three year earlier, Galileo will use Earth's gravitation to change its flight direction and pick up about 8,000 miles per hour.

Each gravity-assist flyby requires about three rocket-thrusting sessions, using Galileo's onboard retropropulsion module, to fine-tune the flight path. (Asteroid encounters require similar manoeuvres to obtain the best observing conditions.)

Passing the Earth for the last time, the spacecraft's scientific equipment will make thorough observations of the planet, both for comparison with Venus and Jupiter and to aid in Earth studies.



Galileo in orbit around Jupiter The probe will be the first man-made spacecraft to orbit one of the outer planets. *NASA/JPL*

Second Asteroid - Nine months later, Galileo may have a second asteroid-observing opportunity. Ida is about 30 km across; like Gaspra, it is believed to represent the majority of main-belt asteroids in composition, though there are believed to be differences between the two.

Relative velocity for this flyby will be nearly 45,000 km per hour, with a planned approach of about 1,000 km.

Approaching Jupiter - Some two and a half years after leaving Earth for the third time and five months before reaching Jupiter, Galileo's probe must separate from the orbiter which has been carrying it since before launch.

The spacecraft turns to aim the probe precisely for its entry point in the atmosphere, spins up to 10 rpm and releases the spin-stabilised probe. Then the Galileo orbiter manoeuvres again, in order to aim for its own Jupiter encounter and resumes its scientific measurements of the interplanetary environment, which have been underway since the launch more than five years before.

At Jupiter

Early in December 1995 the Galileo orbiter and probe will approach Jupiter separately. They will have travelled about 4 billion km in a complex multiple looping path for more than six years. For the last 60 days of the approach, the orbiter carries out a comprehensive programme of observations of Jupiter and measurements of its environment in space.

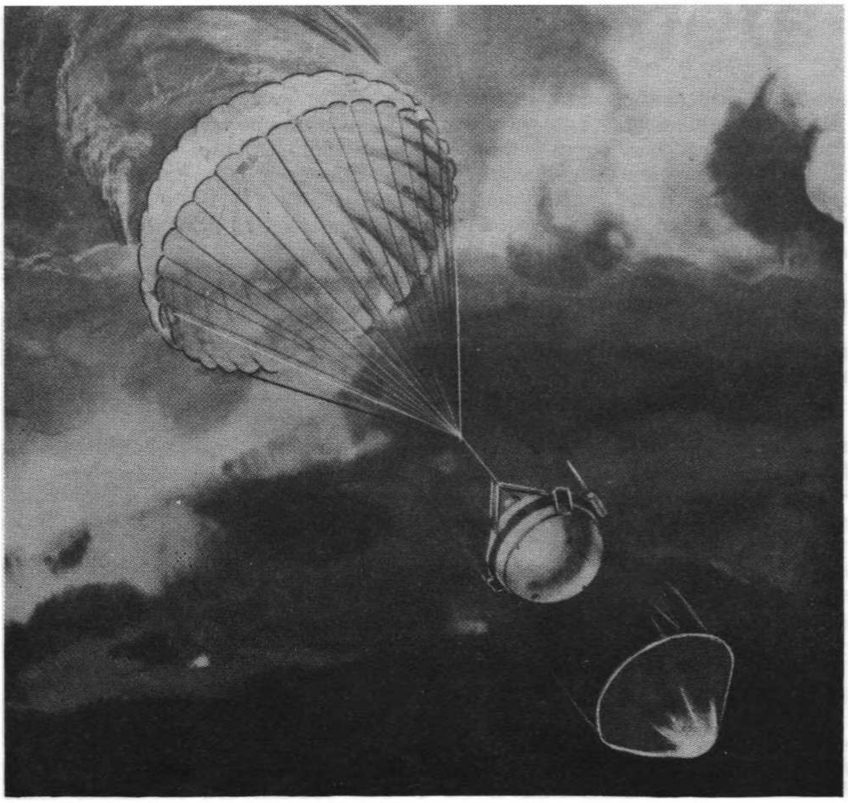
The probe will enter the atmosphere to make direct measurements. The orbiter will fly close by Io, receive the probe signals for relay to Earth and go into orbit around Jupiter, all in a period of about seven hours.

While the probe is still approaching Jupiter, the orbiter will have its first two satellite encounters. After passing within 33,000 km of Europa, it will fly about 1,000 km above Io's volcano-torn surface, about 1/20th of the closest flyby altitude of Voyager in 1979.

A few hours later, the probe will enter the upper atmosphere at more than 47 km per second and slow by aerodynamic braking in about two minutes before dropping its heat shields and deploying its parachute. This will allow it to float down about 200 km through the clouds, passing from a pressure of 1/10th that on Earth's surface to about 25 Earth atmospheres in 75 minutes. The probe batteries are not expected last beyond this point, and the relaying orbiter will move out of reach.

About 214,000 km above, the orbiter will receive, store and transmit the probe's science data. Next, the orbiter must thrust with its main engine to go into orbit around Jupiter.

This orbit, the first of ten planned, will have a period of about eight months. A close fly-by of Ganymede in July 1996 will shorten the orbit, and each time the orbiter returns to the inner zone of satellites it will make a gravity-assist close pass over one or another of them to change its orbit



The Galileo descent module jettisons its heat shield as it plunges through Jupiter's atmosphere. NASA/JPL

while making close observations. These satellite encounters will be at altitudes as close as 200 km above surfaces. Throughout the 22-month orbiter phase, Galileo will continue observing the planet and the sateiiites and gathering data or. the magnetospheric environment.

Galileo's scientific experiments will be carried out by more than 100 scientists from six nations. NASA has appointed 15 interdisciplinary scientists whose studies reach across more than one Galileo instrument data set.

Spacecraft

The Galileo mission and systems were designed to investigate three broad aspects of the Jupiter system: the planet's atmosphere, the satellites and the magnetosphere. The spacecraft is in three segments to focus on these areas: the atmospheric probe; a non-spinning section of the orbiter carrying cameras and other remote sensors; and the spinning main section of the orbiter spacecraft which includes the propulsion module, the communications antennae, main computers and most support systems as well as the fields and particles instruments, which sense and measure the environment directly as the spacecraft flies through it.

The probe will enter the atmosphere about six degrees north of the equator. It weighs just under 340 kg and includes a deceleration module to slow and protect the descent module, which carries out the scientific mission.

The deceleration module consists of an aeroshell and an aft cover, designed to block the heat generated by slowing the probe's arrival speed of about 160,000 km per hour to subsonic speed in less than two minutes.

After the covers are released, the descent module deploys its 2.5 m parachute and its six instruments, the control and data system and the radio-relay transmitter go to work. Operating at 128 bits per second, the dual L-band transmitters send nearly identical streams of scientific data to the orbiter. Probe electronics are powered by long-life batteries with an estimated capacity of about 18 amp-hours on arrival at Jupiter.

Probe instruments include an atmospheric structure instrument group measuring temperature, pressure and deceleration; a neutral mass spectrometer and a helium-abundance interferometer supporting atmospheric composition studies; a nephelometer for cloud ar.d cloud-particle observations; a net-ilux radiometer measuring the difference, upward *versus* downward, in radiant energy flux at each altitude and a lightning/radio-emission instrument with an energetic-particle detector, measuring electromagnetic waves (including light and radio-frequency) associated with lightning and energetic particles in the radiation belts of Jupiter.

The orbiter, in addition to delivering the probe to Jupiter and relaying probe data to Earth, will support all the scientific investigations of Venus, the Earth and Moon, asteroids and the interplanetary medium, Jupiter's satellites and magnetosphere and observation of the giant planet itself.

The orbiter weighs about 2,400 kg, including about 1,100 kg of rocket propellant to be expended in some 30 relatively small manoeuvres during the long gravity-assisted flight to Jupiter, the large thrust manoeuvre which puts the craft into its Jupiter orbit and the 30 or so trim manoeuvres planned for the satellite tour phase.

The retropropulsion module consists of 12 10-Newton thrusters, a single 400-Newton engine and the fuel, oxidiser and pressurising-gas tanks, tubing, valves and control equipment. The propulsion system was developed and built by Messerschmitt-Bolkow-Blohm and provided by the Federal Republic of Germany.

The orbiter's maximum communications rate is 134 kilobits per second (the equivalent of about one black-and-white image per minute); there are other data rates, down to 10 bits per second, for transmitting engineering data under poor conditions. The spacecraft transmitters operate at S-band and X-band (2295 and 8415 megaHertz) frequencies.

The high-gain antenna is a 4.8 m umbrella-like reflector unfurled after the first Earth flyby. Two low-gain antennae (one pointed forward and one aft, both mounted on the spinning section) are provided to support communications during the Earth-Venus-Earth leg of the flight and whenever the main antenna is not deployed and pointed at Earth. The despun section of the orbiter carries a radio relay antenna for receiving the probe's data transmissions.

Electrical power is provided to Galileo's equipment by two Radioisotope Thermoelectric Generators. Heat produced by natural radioactive decay of plutonium is converted to approximately 500 Watts of electricity (570 Watts at launch, 480 at the end of the mission) to operate the orbiter equipment for its eight-year active period. This is the same type of power source used by the Voyager and Pioneer Jupiter spacecraft in their long outer-planet missions.

Most spacecraft are stabilised in flight either by spinning around a major axis or by maintaining a fixed orientation in space, referenced to the Sun and another star. Galileo represents a hybrid of these techniques, with a spinning section rotating ordi-

narily at 3 rpm, and a "despun" section, which is counter-rotated to provide a fixed orientation for cameras and other remote sensors.

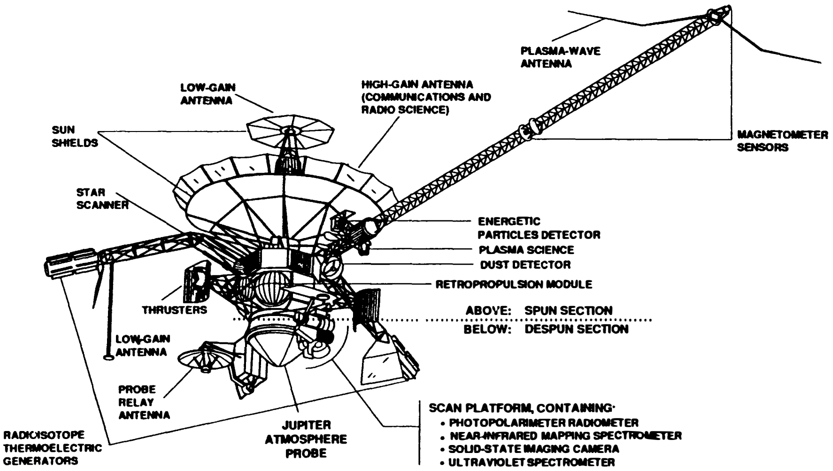
Instruments which measure fields and particles, together with the main antenna, the power supply, the propulsion module, most of the computers and control electronics, are mounted on the spinning section. The instruments include magnetometer sensors mounted on a 11 m boom to escape interference from the spacecraft; a plasma instrument detecting low-energy charged particles and a plasma-wave detector to study waves generated in planetary magnetospheres and by lightning discharges; a high-energy particle detector and a detector of cosmic and Jovian dust.

The despun section carries instruments and other equipment whose operation depends on a fixed orientation in space. The instruments include the camera system; the near-infrared mapping spectrometer to make multispectral images for atmosphere and surface chemical analysis; the ultraviolet spectrometer to study gases and ionised gases and the photopolarimeter radiometer to measure radiant and reflected energy. The camera system is expected to obtain images of Jupiter's satellites at resolutions from 20 to 1,000 times better than Voyager's best.

This section also carries a dish antenna to track the probe in Jupiter's atmosphere and pick up its signals for relay to Earth. The probe is carried on the despun section, and before it is released the whole spacecraft is spun up briefly to 10 rpm in order to spin-stabilise the probe.

The Galileo spacecraft will carry out its complex operations, including manoeuvres, scientific observations and communications, in response to stored sequences which are interpreted and executed by various on-board computers. These sequences are sent up to the orbiter periodically through the Deep Space Network in the form of command loads.

THE GALILEO SPACECRAFT



Ground Systems

Galileo communicates with Earth *via* NASA's Deep Space Network, which has a complex of large antennae with receivers and transmitters located in the California desert, another in Australia and a third in Spain, linked to a network control centre at the Jet Propulsion Laboratory (JPL) in Pasadena, California. The spacecraft receives commands, sends science and engineering data and is tracked by doppler and ranging measurements through this network.

At JPL, mission controllers including about 275 scientists, engineers and technicians will be supporting the mission at launch, increasing to nearly 400 for Jupiter operations. Their responsibilities include commanding the spacecraft, interpreting the engineering and scientific data it sends in order to understand how it is performing and responding and analyzing navigation data obtained by the Deep Space Network. The controllers use a set of complex computer programs to help them control the spacecraft and interpret the data.

Because the time delay in radio signals from Earth to Jupiter and back is more than an hour, the Galileo spacecraft was designed to operate from programs sent to it in advance and stored in spacecraft memory. A single master sequence program can cover four weeks of quiet operations between planetary and satellite encounters. During busy Jupiter operations, one program covers only a few days. Actual spacecraft tasks are carried out by several subsystems and scientific instruments, many of which work from their own computers controlled by the main sequence.

Designing these sequences is a complex process balancing the desire to make certain scientific observations with the need to safeguard the spacecraft and mission. The sequence design process itself is supported by software programs, for example, which display to the scientists maps of the instrument coverage on the surface of an approaching satellite for a given spacecraft orientation and trajectory. Notwithstanding these aids, a typical three-day satellite encounter may take efforts spread over many months to design, check and recheck; the controllers also use software designed to check the command sequence further against flight rules and constraints.

The spacecraft regularly reports its status and health through an extensive set of engineering measurements. Interpreting these data into trends and averting or working around equipment failures is a major task for the mission operations team. Conclusions from this activity become an important input, along with scientific plans, to the sequence design process. This too is supported by computer programs written and used in the mission support area.

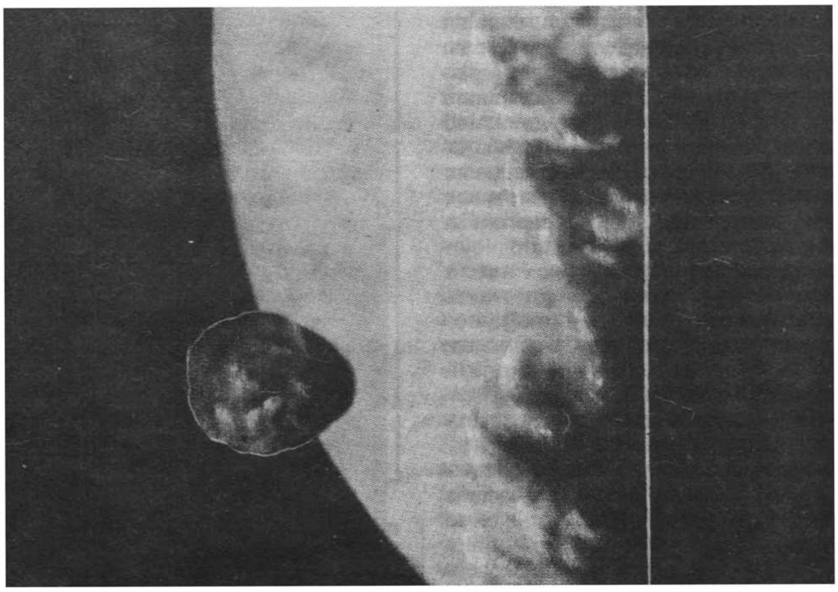
Navigation is the process of estimating, from radio range and doppler measurements, the position and velocity of the spacecraft so as to predict its flight path and design course-correcting manoeuvres. These calculations must be done with computer support. The Galileo mission, with its complex gravity-assist flight to Jupiter and 10 gravity-assist satellite encounters in the Jovian system, is extremely dependent on consistently accurate navigation.

In addition to these programs which directly operate the spacecraft and are periodically transmitted to it, the mission operations team uses software amounting to 650,000 lines of programming code in the sequence design process; 1,615,000 lines in the telemetry interpretation; and 550,000 lines of code in navigation. These must all be written, checked, tested, used in mission simulations and, in many cases, revised before the mission can begin.

Science investigators are located variously at JPL or at their home laboratories, linked by computer communications. From either location, they are involved in developing the sequences affecting their experiments and, in some cases, helping to change replanned sequences to follow up on unexpected discoveries with second looks and confirming observations.

The Successes of Phobos-2

THE Soviet Union's Phobos mission was branded a failure in the West after the loss of the two probes. But as *Yuri Zaitsev* of the Institute of Space Research at the USSR Academy of Sciences reports the mission achieved many of its goals and returned excellent data and images of Mars, its moon Phobos and the interplanetary environment.



Phobos in orbit around Mars. *Unless otherwise stated photos: USSR Academy of Sciences*

By Yuri Zaitsev
Institute of Space Research
The USSR Academy of Sciences
Via Novosti Press Agency

The Phobos Mission

The Phobos mission was an international mission involving fourteen countries and the European Space Agency. The mission was the first to explore in detail one of the minor bodies of the Solar System, the Martian moon Phobos.

The two Phobos probes were launched from the Baikonur Cosmodrome on July 7 and July 12, 1988 by Proton boosters.

The loss of the first Phobos probe came early in the mission. In early September contact was lost with Phobos-1 because of an error in a command transmitted from Earth. As a result, its orientation system was switched off and its solar panels stopped facing the Sun. With the onboard systems starved of power, the probe was unable to respond to radio signals from Earth.

On January 29, 1989, 200 days after blast off, Phobos-2 was injected into a heavily elongated elliptical orbit above Mars' equator. Subsequent corrections gradually transformed the orbit into a circular observation orbit (350 km above the orbit of Phobos).

From this orbit, at a distance of between 860 km and 1,130 km from Phobos, the first television session was conducted to gather information about the position and orbit of Phobos in preparation for its manoeuvres close to the moon.

On March 21, the probe assumed a near-synchronous orbit with the Martian satellite. One more television session was completed while preparations were carried out to place the probe over the surface of Phobos facing away from Mars at a distance of 35 km. Once there the spacecraft was to have begun an entirely novel phase of its flight - moving side by side with the moon and making elaborate manoeuvres over its surface. Then, hovering some 50 metres above the surface, Phobos-2 would take television pictures and make other investigations of the surface by bombarding it with laser and ion-beams.

At the end of this 'grazing' flight, two landing modules - one permanent and the other mobile - were to have been dropped onto the surface of Phobos.

But, unexpectedly, on March 27, after the probe was put into a position to take television pictures of Phobos and send the information back to Earth, radio contact with the probe was lost. Roald Kremnev, chief designer at the G.N. Babakin Research and Testing Station that built the probe, said that all systems were in full working order when contact was lost. There has been no final conclusion as to why the probe failed.

The Phobos Mission Was a Success

The mission consisted of three stages. The first dealt with studies during the cruise between Earth and Mars, the second with Mars and the third with Phobos.

During the interplanetary flight, X-ray emissions by the Sun were investigated by the Terek experiment devised by Soviet and Czechoslovak scientists and carried by Phobos-1. The experiment functioned normally until contact was lost with the probe. Of the 50 planned observation sessions 14 were held producing 140 high quality pictures of the Sun and its corona.

The Terek solar telescope, specially designed for the Phobos mission, made use of oblique incidence X-ray optics and new spectrally selective mirrors of normal incidence with multiple coatings. The experiment yielded unique data on the distribution and dynamics of plasma in the atmosphere of the Sun and in various temperature ranges corresponding to the chromospheric coronal transition layer both in a quiet and an agitated corona.

Of special interest were observations of coronal holes that suffer from a deficit of hot plasma and are generally associated with sources of high-velocity streams of charged particles. Little was known about these coronal holes, especially those located in the pre-equatorial zone of the solar disc.

The Terek experiment was the first to measure the polarisation of solar radiation at the frequency of the helium line at 304A. In a flare up on August 27, 1988, ejection of plasma from the Sun to a distance of about one solar radius with a practically fully polarized radiation was photographed.

Solar activity was also studied by means of the X-ray photometer RF-15 (developed by the USSR and Czechoslovakia), energy and mass spectrometers of solar cosmic rays SLED (Hungary, Ireland, the USSR and FRG) and LET (Hungary, the USSR and ESA) and gamma-ray burst spectrometers VGS and LILAS (France and the USSR). The data they obtained on an extremely large active region of the Sun from March 4 to 18, 1989, when Phobos-2 was operating in Mars orbit, is very interesting. It was a period when a series of major X-ray and gamma-ray flares occurred in the current cycle of solar activity and there was a resulting increase in the flux of

accelerated charged particles.

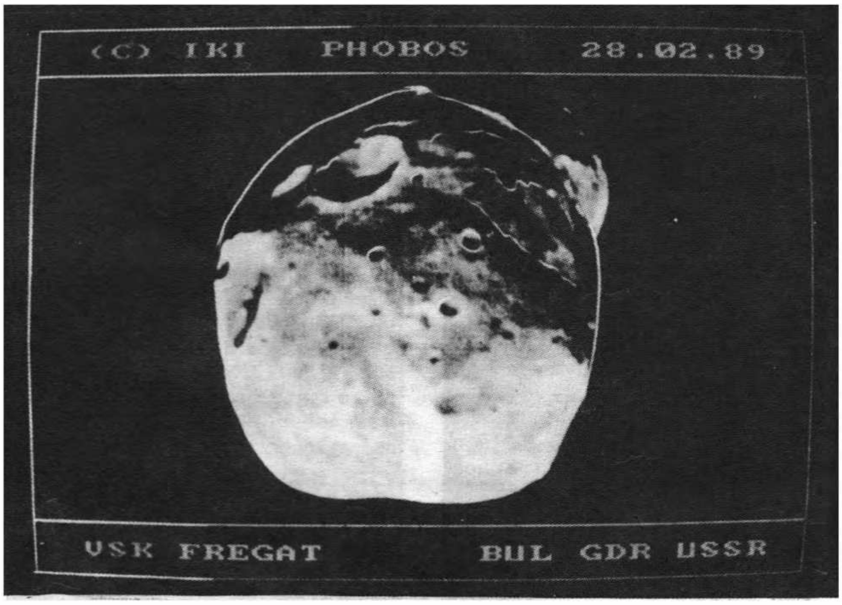
The VGS and LILAS gamma-ray burst spectrometers were also employed to investigate cosmic gamma-ray bursts. This is a phenomenon discovered in the 1970s. For a brief period of time, not longer than a few dozen seconds, there appears a source of gamma-rays with a flux thousands of times greater than those from the brightest stationary sources in the same energy band. The frequency of such events is not great and seldom if ever exceeds a few hundred bursts a year.

Phobos-1 and 2 registered more than one hundred bursts of hard gamma-ray emission. The time resolution they have achieved is the highest in contemporary gamma-ray astronomy. In one event the variability of a gamma-ray flux with a characteristic time of less than 1 millisecond was measured, an emission with energies of several dozen MeV was registered and spectral lines with energies of more than 1 MeV were discovered. Various models of gamma-ray bursts are now being considered on the basis of the data obtained.

On October 24, 1988, Phobos-2's VGS spectrometer registered a gamma-ray burst which proved to be the most intense of all non-stationary events ever observed in the gamma-ray band. Work is now underway to elucidate the nature of this gamma-ray burst.

Solar oscillations were studied from the Phobos probes by means of the instrument IFIR developed by Switzerland, France, the USSR and the European Space Agency. The data received is being processed.

Among the unquestionable achievements of the Phobos project



A close up of the surface of Phobos taken on February 28 *Novosti*

have been measurements made from onboard Phobos-2 of plasma components in the vicinity of Mars. The magnetic field was measured by two three-component ferro-sonde magnetometers, MAGMA (Austria and the USSR) and FGMM (the GDR and the USSR), both having almost identical characteristics. Wave emissions were measured by means of the APV-F plasma wave analyzer (the USSR, Poland, Czechoslovakia and the European Space Agency).

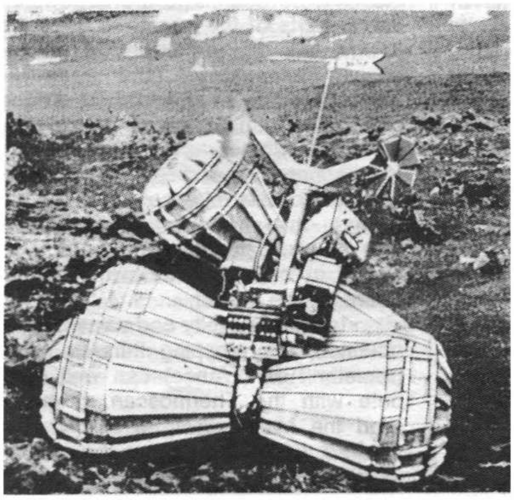
Since earlier Mars expeditions carried no instruments to measure plasma parameters in broad angle and energy bands, no information was obtainable on ion content and characteristics of various sorts of ions in near-Mars space. A knowledge of these parameters of the Martian ionosphere, however is essential for understanding the interaction between the planet and the solar wind.

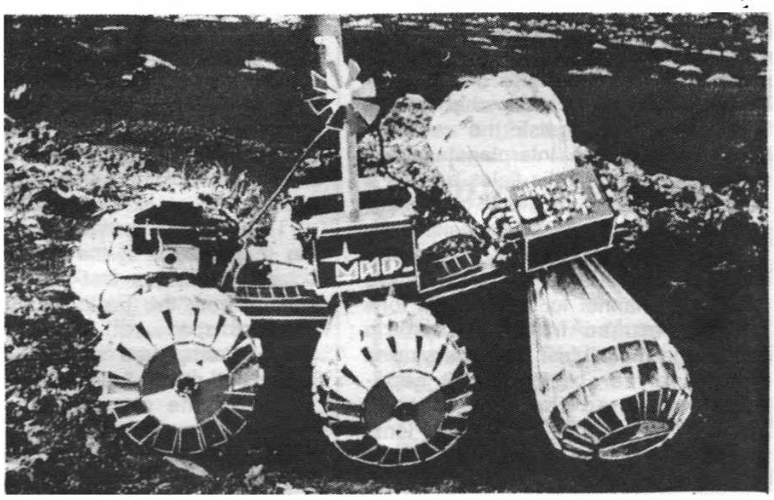
The high manoeuvrability of Phobos-2 and numerous changes of its orbit made it possible to investigate both the area where the solar wind interacts with the planet's magnetic field and atmosphere, and the planet's extended magnetic tail, formed when the solar wind flows around Mars.

It turned out that the Martian magnetosphere, just like the Earth's has distinct structures, such as a magnetopause (the boundary of the magnetosphere), a plasma layer in the tail of the magnetosphere and also a shock

Soviet Mars Rover

The Soviet Union is planning a mission to place a rover on the surface of Mars in the mid-1990s. Prototype versions of the rover have been built and tested. The photographs below show the prototype rover traversing a rocky desert in the USSR.





The surface of Mars imaged by the Thermoscan instrument. This type of thermal image reveals the planet's 'own' thermal radiation, rather than reflected solar light *Novosti*

wave in the solar wind flow in front of the magnetosphere. It was possible to ascertain some other, finer structural details of the Martian magnetosphere.

Inside the magnetosphere, filled with a relatively cold plasma of planetary origin, there are to be found rather frequent islands of a hotter solar plasma. This is evidence of the fact that the weak magnetic field of Mars is closely interwoven with the interplanetary magnetic field, creating a natural 'magnetic' channel for solar plasma to penetrate into the magnetosphere. Such a relationship makes it difficult to distinguish the contributions made by the interplanetary and the planetary magnetic fields and as a result parameters of Mars' own magnetic field appear to be unidentifiable.

Magnetic force lines connected with the planet and its atmosphere provide a channel for the loss of ions that are formed from atmospheric atoms and molecules. The energy and mass analyzer of Phobos-2 separately measured the flow of solar plasma (in the main, hydrogen ions) and of the plasma of planetary origin (mainly ions of carbon dioxide, molecular and atomic oxygen) and so determined the rate of escape of planetary ions into the interplanetary medium. This flow is about 2-5x10^{25} ions a second. In other words, the atmosphere of Mars is losing one to two kilograms of substance every second. That may not seem to be a lot but taking into account the high degree of rarefaction of the Martian atmosphere (the pressure on the planets' surface is 1/170th of that on Earth), such losses may have a substantial effect on its evolution.

Indeed, the estimated loss of ionospheric ions from the Martian atmosphere is practically equal to the losses from the Earth's magnetosphere via its magnetic tail. For the Earth, however, such a loss is negligibly small even on a cosmological time scale. At such a rate of escape the Earth's atmospheric oxygen would take 10 billion years to disappear, while for Mars which has a mass of about one tenth that of the Earth, the loss of 2 kg/sec is equivalent to disappearance from the planet's surface of a one to two metre layer of water in 4.5 billion years, i.e. during the entire history of Mars.

It can be concluded from this that if Mars had not possessed a sufficiently powerful magnetic field in the past the interaction of the solar wind even with the much denser atmosphere at earlier stages of the planet's evolution could have led to a considerable erosion of its atmosphere. It is not therefore ruled out that the absence of a sufficiently strong magnetic field on Mars and Venus is the main reason why these planets lost their water (a source of volatile substances) which they had upon accretion from protoplanetary substance.

Thermal Images

Among the more interesting results of investigations of Mars itself are images of the planet's surface obtained in the infrared by means of the Soviet Thermoscan instrument. In these images the planet shows its 'own' thermal radiation, rather than reflected solar light. (Part of the solar energy reaching the surface of Mars is absorbed, heats it and is re-emitted in the infrared band. The higher the temperature of the surface the greater the brightness of thermal emission.)

This classic method of measuring the temperature of the planets of the solar system was first used in observations from the Earth and then from onboard spacecraft. It was also repeatedly employed in Mars investigations, but never before has a visible image of the planet been built by means of thermal emissions. The only exception is our Earth - its 'thermal portraits' are transmitted regularly from weather satellites.

The heart of the Thermoscan is a highly sensitive infrared receiver of radiation. It is cooled by an onboard closed cycle cryogenic device which utilises liquid nitrogen as a coolant. Instruments like this have never before been put in long distance spacecraft either by the USSR or elsewhere.

From a circular orbit some 6,000 km in radius, the Thermoscan surveyed a considerable part of the equatorial zone of Mars' surface, in a sweep approximately 1,500 km wide and having a resolution of some two kilometres. Thermal images sent back to Earth are distinguished above all by sharpness and high contrast. In this respect they are even superior to the best television pictures of Mars. It was the first time that a detailed thermal map of the planet had been obtained.

The temperature to which the surface is heated depends on the surface's physical characteristics, especially the degree of soil fragmentation. Thus thermal images simultaneously offer information on the macroscopic features of the surface (terrain) and on its microstructure.

Along with conducting 'thermal' surveys, the Thermoscan synchronously received short-wave radiation reflected by the planet's surface. As a result, two brightness values were obtained at the same time at both thermal and visible wavelengths. That is very important for interpreting the measurement data.

Another instrument called KRFM (a combined radiometer and spectrophotometer, built by the USSR) registered Mars' emission not in two but in sixteen parts of the spectrum. Six of them were in the thermal band and ten at shorter wavelengths, enabling photometric measurements to be carried out in the near ultra-violet and visible parts of the spectrum. However, this instrument could not construct images. In observational resolution too it was inferior to the Thermoscan. But thanks to the large number of parts of the spectrum used the KRFM enjoyed a number of advantages. For example, the measurements it made in the carbon dioxide absorption band allowed it to determine the temperature of the Martian stratosphere. In addition, KRFM data on the specific distribution of brightness in the short-wave band offer a way of elucidating optical characteristics of aerosol particles in the atmosphere of the planet.

In terms of novelty and value of data obtained, the mapping infrared spectrometer ISM (France) can well compete with the Thermoscan. It measured the Mars spectrum in the near infrared, which is optimum for analyzing the mineralogical content of soil. A

series of absorption bands characteristic of various minerals is located in this range.

The instrument operated in 128 parts of the spectrum. The measurements it made extended to a considerable part of the planet's equatorial zone. After the data have been fully processed, it is planned to determine the distribution of the mineralogical characteristics of rocks, notably to find their degree of hydration, that is, the content of bound water in minerals. Scientists are also going to make maps of the pressure and height of the terrain (from absorption lines of carbon dioxide, the main component of the Martian atmosphere) and to evaluate water vapour content in the atmosphere.

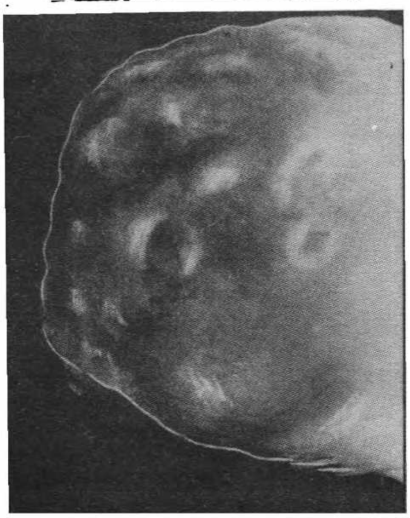
The results of preliminary approximate analysis point to considerable variations in spectral reflective characteristics of the surface, which is a new element in our knowledge of Mars. Data on the degree of hydration of minerals suggests the presence of sedimentary rocks on Mars - one of the decisive factors in understanding the planet's evolution.

Phobos-2 also studied the vertical structure of the planet's atmosphere. To that end two linked instruments were used, one of which was made in France, the other in the USSR. Investigations were carried out by an original method, one that has never before been employed on planetary probes. Basically, the method is to measure the spectrum of solar radiation that passes through the Martian atmosphere when the Sun is seen near the edge of the planet - either disappearing behind it or appearing above it, that is, when the planet eclipses the Sun. Solar rays in this case move tangentially and encounter the largest amount of atmospheric matter - gas and dust. Solar spectra obtained in these conditions at different moments of time correspond to different heights above the planet's surface, and analyzing them can produce a distribution of various components in the atmosphere with altitude. Measurements were made in bands containing the spectral lines of carbon dioxide, ozone and water vapour.

Preliminary analysis of the data has shown that the water vapour content in the atmosphere of Mars at altitudes of 20 to 60 km is on average close to one ten thousandth of the main component - carbon dioxide. Ozone content varies considerably with altitude. A vertical cross-section of the relative content of atmospheric gases on Mars has been obtained for the first time.

Photographing Phobos

A series of photographs of the planet's satellite Phobos is one of the major achievements of the Phobos project.



One of the final images of the Martian moon before contact was lost with Phobos-2. The photograph was taken on March 25.

Photographing distant space objects, with pictures returned by radio, is an extremely challenging scientific and engineering task. A set of instruments was designed for the television experiment, consisting of three TV cameras, a spectrometer, a control system and a video recording system. As a receiver of emissions, the TV camera and spectrometer used a so-called charge feedback instrument or PEA matrix. This is a silicon monocrystal, the surface of which contains hundreds of thousands of sensors. Incident light is transformed into electrical signals in proportion to its intensity in each part of the image. Photographic plates, which have always been a component of ground-based astronomical cameras, usually register only seven out of every 1,000 light quanta. The charge-feedback instrument registers 700 out of every 1,000 quanta.

The German Democratic Republic developed a video memory to store over 1,000 TV pictures for subsequent transmission to Earth.

The development of electron and microprocessor units, the final assembly of the complex and its functional tests were done by Bulgarian scientists and specialists. They undertook perhaps the most difficult part of the job - piecing together a system from separate elements.

At various stages, scientists and experts from France, the US and Finland gave a helping hand to the systems developers. This help came with absolutely no strings attached and was motivated by interest in the project and its success.

The video spectrometric system was designed to perform two different tasks. The first was to collect navigational information needed to determine the mutual position of the interplanetary probe and the Martian satellite and the second was to obtain data on the figure of Phobos and the structure, microstructure and composition of its surface.

Prompt navigational processing of the pictures of Phobos sent back from the Phobos-2 probe increased the accuracy of predicting the position of the Martian moon approximately tenfold, which helped to correct the probe's orbit and bring it to within 200 km of Phobos.

The navigational measurements are of much scientific interest as well. In particular, they give more precise characteristics of tidal links between Phobos and Mars, of the libration movement of Phobos, its mass and density and offer some information for analyzing its inner structure.

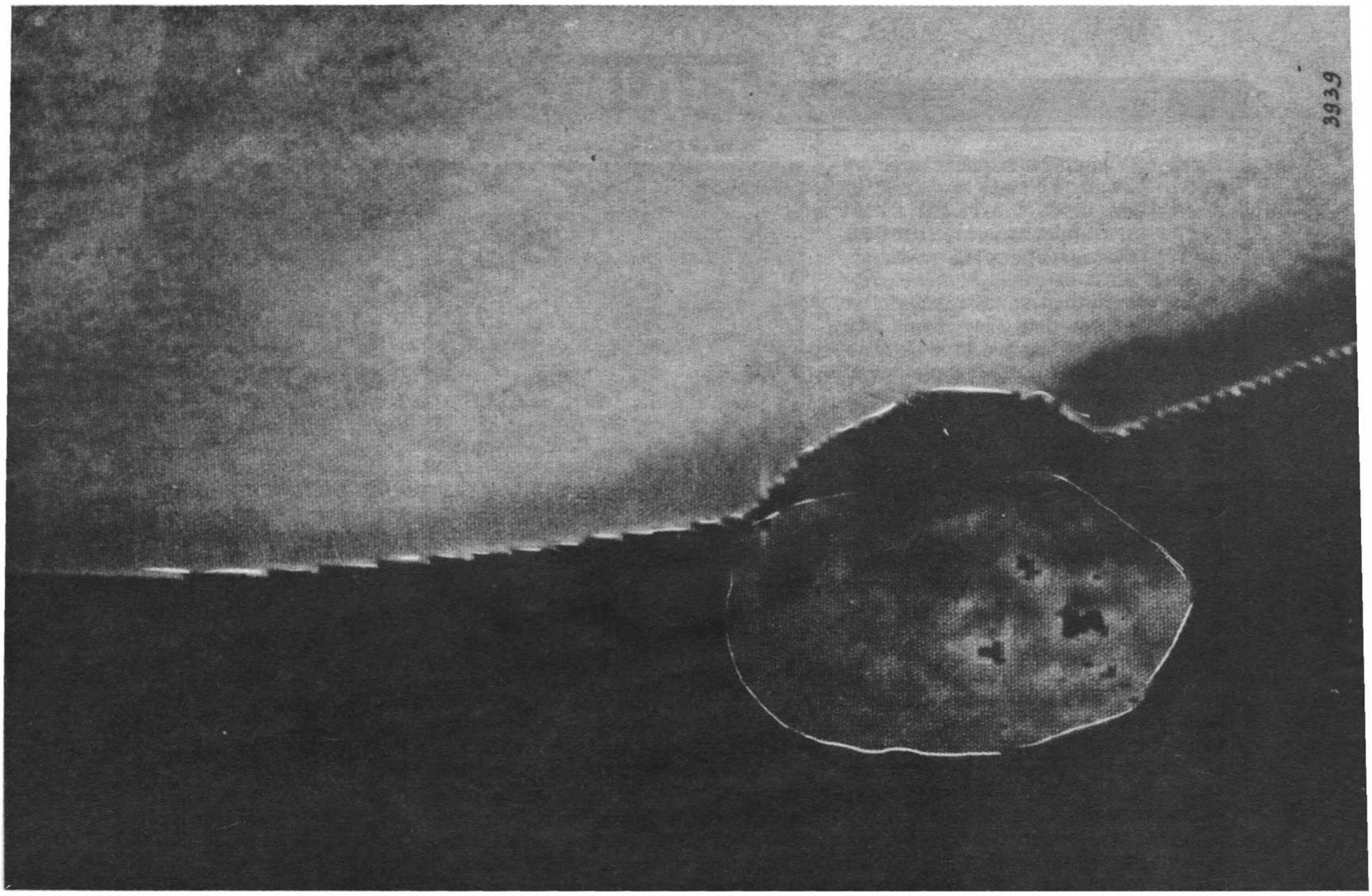
In the course of the experiment, some 40 images of Phobos were obtained, photographed from distances ranging between 200 and 1,100 km and covering more than 80% of its surface. The resolution of the pictures taken at the minimum distance is 40 metres. Television pictures taken from different angles and under different illumination make it possible to analyze the dependence of the brightness of the Phobos surface upon the angle and to look into microstructures determining its parameters, for example, the characteristic size of regolith particles. This data is essential for studying processes that occur during meteorite bombardment of the surface of Phobos and for assessing the mechanical and thermophysical properties of its substance. Phobos' average reflectivity is very low, about 4% and is practically independent of the wavelength. So this data suggests that the surface material of Phobos is in the main close to carbonaceous chondrites - one of the meteorite types. Analysis of the ISM results points to a marked heterogeneity of the surface composition and also to a lower water content in Phobos rock minerals than was expected. It has been established that the daytime temperature on Phobos is about 300 degrees K (27 degrees C).

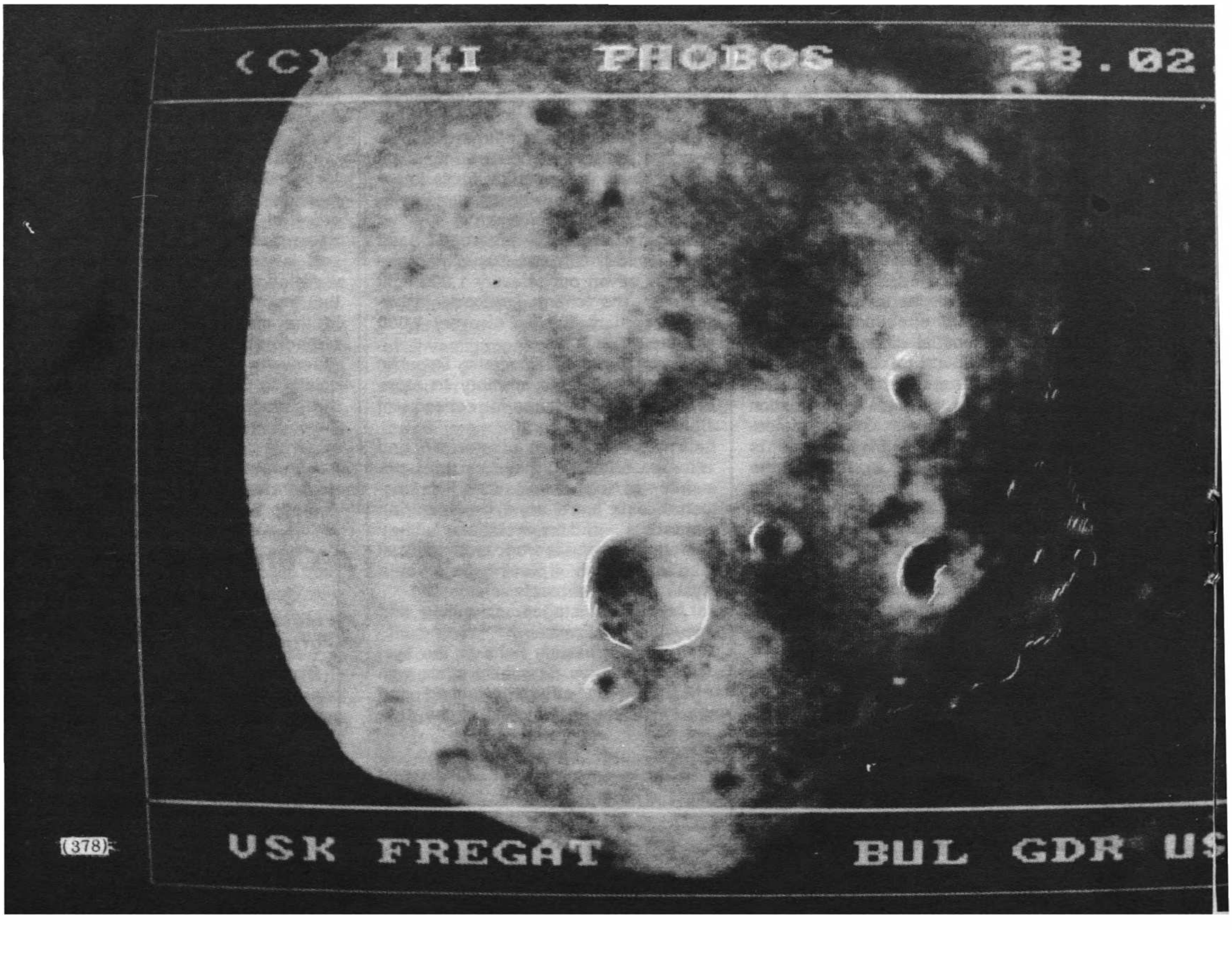
Centre Pages:

Top Left: **Phobos orbits with Mars dominating the background.**

Bottom Left: **A close up of the surface of Phobos recorded on February 28.**

Right: **Phobos is seen here orbiting against the backdrop of the Martian surface.** ***Novosti***





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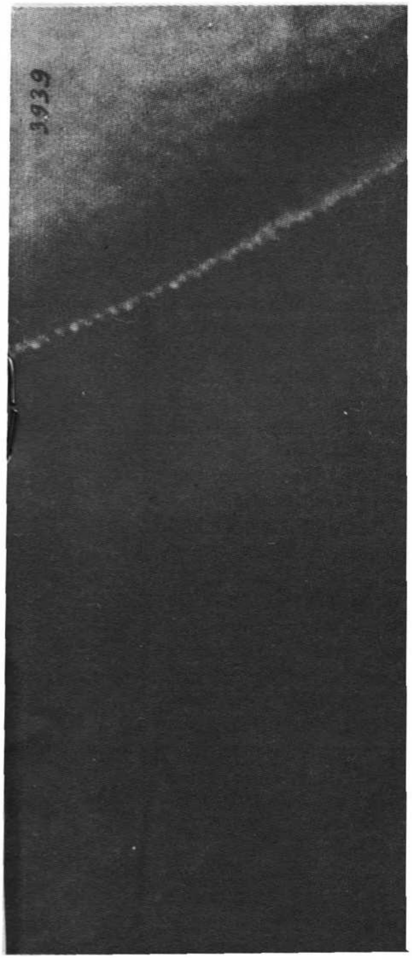
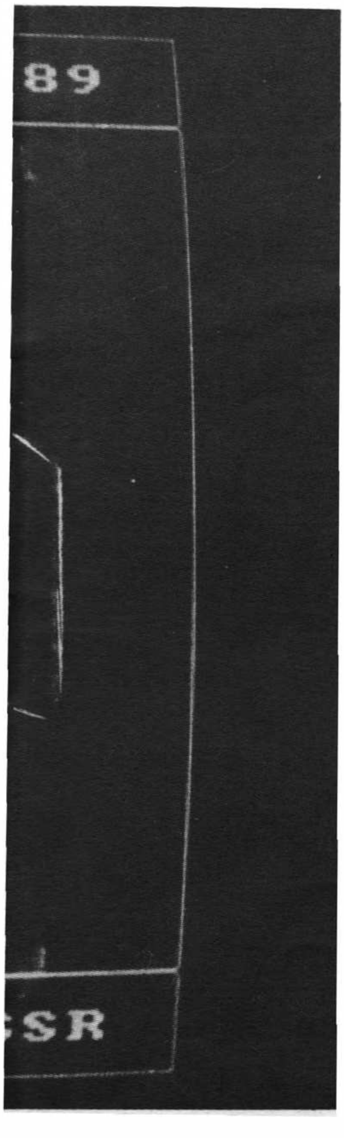


PHOBOS

THE SUCCESSES OF PHOBOS-2



Energia and Buran at Baikonur

A year ago, on November 15, 1988 the Soviet Union's first Space Shuttle, Buran, blasted off on its maiden voyage. The USSR developed extensive facilities at the Baikonur Cosmodrome to support their Space Shuttle and its Energia heavy lift booster. These facilities are much larger than their US counterparts at NASA's Kennedy Space Center and Marshall Space Flight Center. The Soviets adapted and expanded the facilities that had been constructed for their manned lunar programme and its booster. In this article we take a look at these impressive facilities.

By P. Mills

Energia and Buran operations are carried out in an Energia/Shuttle Technical Zone, located in the Cosmodrome's main base area where the initial installations were erected in the early days of the Soviet space programme.

The buildings so far identified in the Energia/Shuttle Technical Zone are:

- ☐ Energia Core Integration Building
- ☐ Shuttle Orbiter Integration Building (also referred to as the Shuttle MIK)
- ☐ Shuttle Checkout Building (also referred to as the Energia/Buran MIK)
- ☐ Vibration Test Facility
- ☐ Energia Integration Building (also referred to as the Energia MIK)

Energia Core Integration Building

The Energia Core Integration Building is a large rectangular shaped building about 274 m long, 160 m wide and 40 m high. Within this building the Energia cores are integrated with their engines and checked out prior to being transported to the Energia MIK.

The core stages are transported to the Cosmodrome from the factory atop a Myasischev Mya 201 M aircraft. These aircraft are converted Myasischev Mya 4 bombers which have had the fuselage stretched and strengthened and the vertical stabiliser replaced by two fins mounted on the tailplane. The aircraft's engines were also uprated to enable it to carry its heavy cargo. The Mya 201 Ms are to be replaced by the Antonov Mriya heavy lift aircraft.

The Energia cores are integrated in a long thin bay about 155 m long, 24 m wide and 35 m high. Engineering shops run along one side of the bay. The entrance to the bay is on the long side of the building.

During integration the cores are fitted in special cradles and surrounded by work platforms. Four Energia cores can be accommodated in this bay, two end to end and side by side. The remainder of this building is probably used for Energia main engine integration and test.

Shuttle Integration Building

The final assembly of the orbiters takes place in the Shuttle Integration Building. It is 300 m long, 240 m wide and 37 m high [1] and covers an area of 72,000 m². There is one central hall and four high bays, each large enough to take one orbiter. Two of the high bays are used for shuttle integration and the others for electrical test/verification. An exterior photograph of this massive building [2] shows that it is of poor quality with rusting pipes and a shabby finish. However the interior is of a better quality.

The orbiter airframes are manufactured in the "G.E. Lozino-Lozinsky" plant at the Tushino Machine Building Factory near Moscow. The factory is part of the Molniya Scientific and Industrial Enterprise Design Bureau, which was incorporated with the Myasischev Design Bureau when it was created in 1976 to work on the Soviet Shuttle [3].

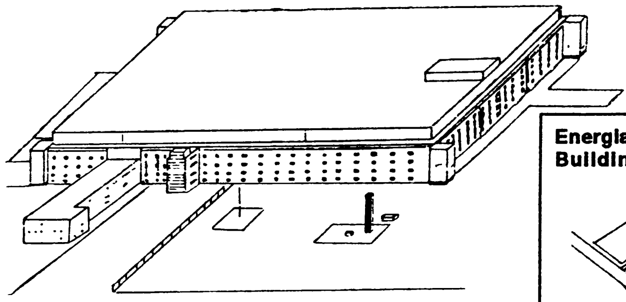
After manufacture the orbiter airframes were transported to the Cosmodrome on the Myasischev 201 M aircraft. To reduce weight, the orbiter lacked its vertical stabiliser and most of the thermal insulation tiles for this flight.

Once at the Cosmodrome the Shuttle was lifted off the aircraft by a mate-demate crane and transferred to the orbiter integration building on a rail mounted dolly [4]. The orbiter enters the building through a large rolling door. The final assembly of the orbiter then takes place.

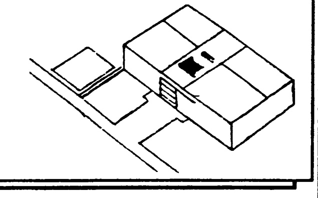
The work includes the integration of the egg shaped propulsion module in the aft of the orbiter. The propulsion module consists of the two orbital manoeuvring engines and the fuel and oxidiser tanks. The module is first fitted on to a rig and is then slid into place in the rear the shuttle.

After this is complete the orbiter's port and starboard rear Reaction Control System (RCS) pods are fitted. The vertical stabiliser and complete thermal protection system are installed. The thermal protection system consists of about 38,000 tiles each installed individually using adhesive applied with a putty knife. This is a complex and difficult task. The ther-

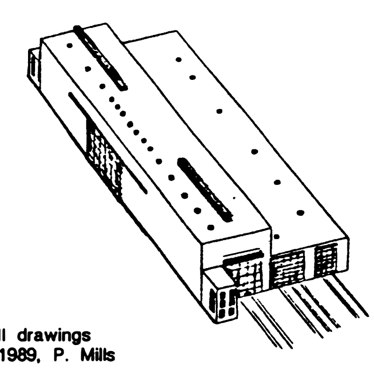
Shuttle Integration Building



Energia Core Integration Building

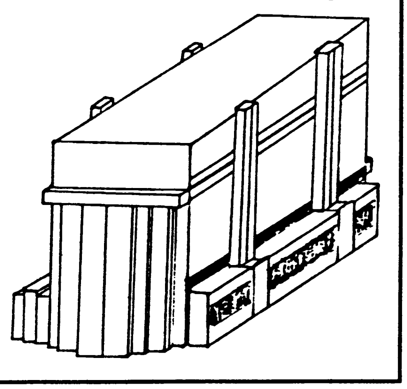


Energia Integration Building



All drawings
©1989, P. Mills

Shuttle Checkout Building



mal protection system is designed to withstand about ten reentries before being replaced.

The orbiter's antennas are tested in one of the two electrical test/verification bays which has been converted into an anechoic chamber. Full sized orbiter models are used for these tests. The other electrical test bay also uses another full sized orbiter model for engineering systems checkout.

After integration is complete the orbiter is transferred to the Shuttle Checkout Building. The shuttle is returned to the Integration Building for servicing after each space flight.

Shuttle Checkout Building

This is a large rectangular shaped building of similar design to the NASA Vehicle Assembly Building at the Kennedy Space Center. It has large sliding doors at one end which reach about half way up the building. Photographs of the inside of the building and television coverage of the rollout of Buran reveal that the doors at the other end reach much higher. Small engineering bays run along the side of this building. It is about 240 m long [1] and 60 m high and is the largest new building in the technical zone.

This building is used to integrate the orbiters with their Energia launch vehicles. The orbiter arrives first and is loaded with its payload. The Energia booster is then towed in and lifted on to a special transporter/erector. The transporter runs on two sets of railway tracks separated 18 m apart. It has a maximum weight of 3,500 tonnes when carrying the shuttle and Energia and is towed by four powerful locomotives.

The orbiter is then attached to its booster and final checkout can begin prior to the roll out to the launch complex. Work platforms swing out from the sides of the bay to give engineers access to the spacecraft and launch vehicle.

Energia can carry a payload canister (similar to the US Shuttle-C concept) instead of an orbiter and these will also be integrated in this building.

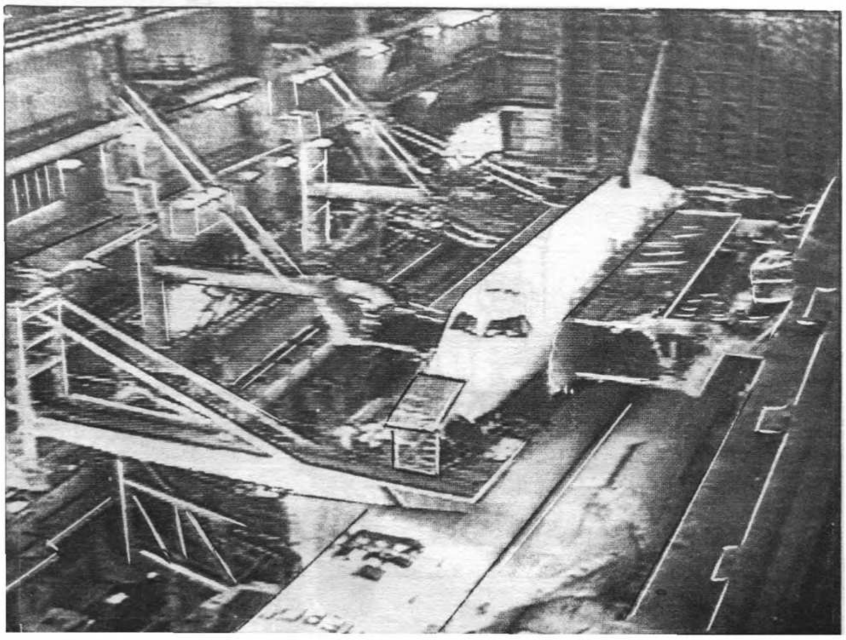
The Shuttle Checkout Building is large enough to easily handle two Energias and shuttle orbiters simultaneously if the need ever arose.

Vibration Test Facility

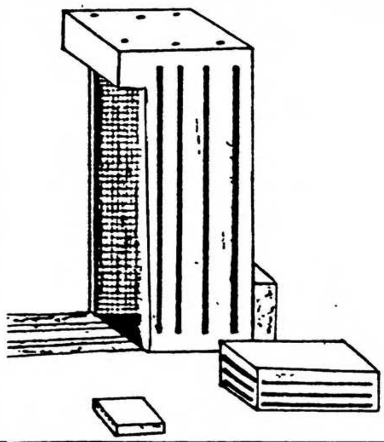
The Vibration Test Facility is similar to the NASA Marshall Space Flight Center's 36 storey Dynamic Test Stand. It is used to subject the vertical Energia/shuttle combination to the conditions expected during a launch. The Vibration Test Facility at Baikonur is about 100 m in height.

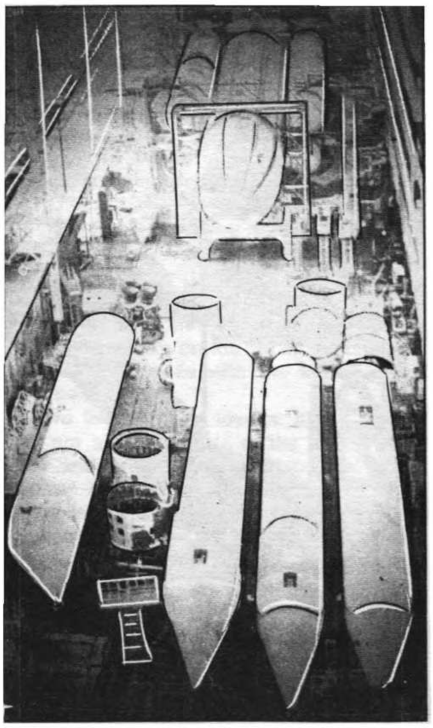
Energia Integration Building

This is a large hangar type building,

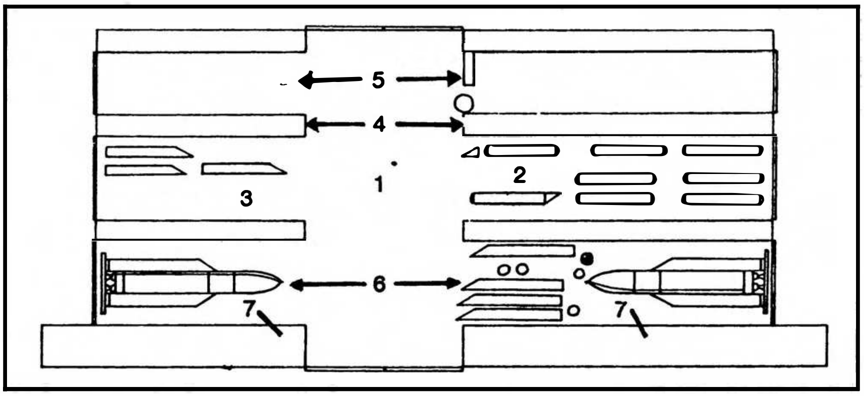


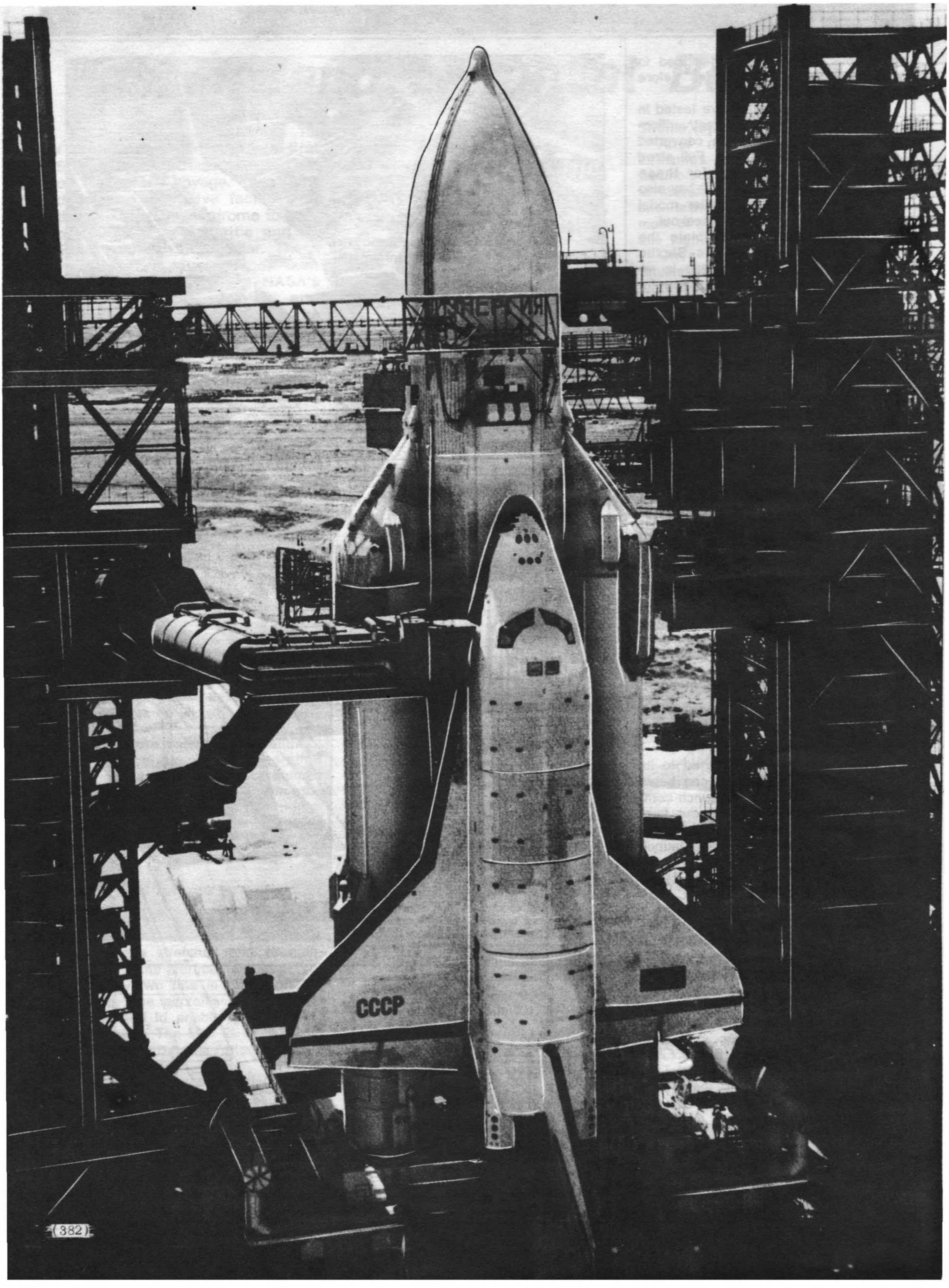
Vibration Test Facility





Top: Buran undergoes final preparations in the Shuttle Checkout Building.
Right: The final integration bay in the Energia Integration Building. *Neville Kidger via Novosti*
Below: Layout of the Energia Integration Building. 1. Central Roadway. 2. 100 m long strap-on booster assembly bay. 3. 70 m long strap-on booster assembly bay. 4. Dividing walls with three rows of windows. 5. Components assembly and test bays. 6. Final integration bays. 7. Walls incorporating seven rows of balconies and windows.

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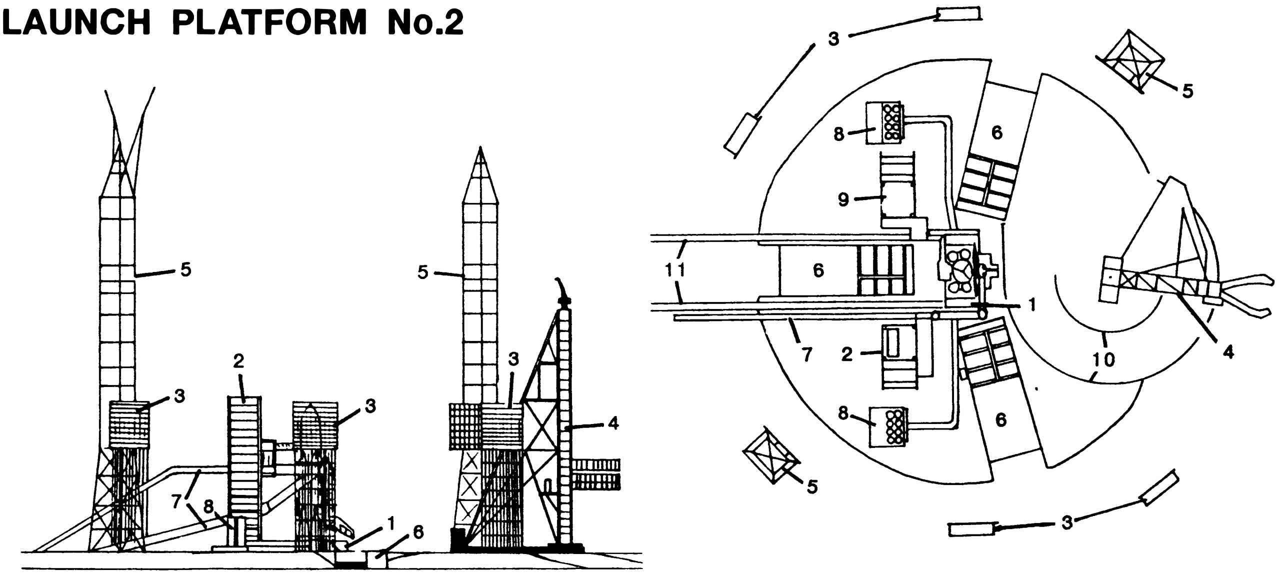
LAUNCH PLATFORM No.2



Key:

1. Concrete launch platform.
2. Left fixed service tower.
3. Floodlight towers.
4. Rotating tower
5. Lightning protection towers
6. Flame trench
7. Access and escape tubes
8. Water reservoirs
9. Right fixed service tower
10. Rotating tower railway track
11. Railway tracks for Transporter
12. Water pipes.

described as being several hundred feet in dimension [5]. The Energia strap-on boosters are assembled here from components which arrive by rail to the Cosmodrome from factories in other areas of the Soviet Union. After assembly they are integrated with the central core which is brought in from the Energia Core Integration Building.

Inside the Energia MIK there are six bays in which the different assembly operations take place. All of the bays are fitted with railway tracks, as this is the standard Soviet practice for transporting rocket stages between locations. The bays are interconnected by a central roadway, also fitted with railway tracks.

The strap-on booster assembly takes place in a pair of bays which face each other across the central roadway. The bays are about 24 m wide, 22 m high, one bay is about 100 m long and the other about 70 m long. The largest bay can assemble up to nine strap-on boosters, three end to end, in three rows. The shorter bay can assemble six boosters. The walls of this bay feature three rows of windows.

Adjacent to the strap-on assembly bays are the pair of Energia final integration bays. The strap-on boosters are moved to these bays where they are fitted with their RD170 rocket engines. The final Integration bays are again opposite each other and are the same lengths as the two strap-on booster bays but are much higher and about 28 m wide. On one side of these bay is a wall which features at least seven rows of balconies and windows.

The Energia core is brought into the bay by rail and integrated with the strap-on boosters. Once this is complete the launch vehicle is fitted with a Mobile Launcher Mating Unit (MLMU). The MLMU stays with the vehicle until launch and can be reused. It connects pneumatic, hydraulic and electrical systems on the launch vehicle with the launch complex service or the test equipment in the assembly building.

After the fitting of the MLMU is complete the launch vehicle is hoisted up and lowered onto a rail mounted flatbed to take it to the Shuttle checkout building. This loader is later integrated with the Transporter/Erector and stays with the launch vehicle until it reaches the launch pad.

The exact purpose of the remaining two bays is unknown, they are probably used for component test and assembly.

Left: Buran and its Energia booster on the launch pad prior to its first flight.

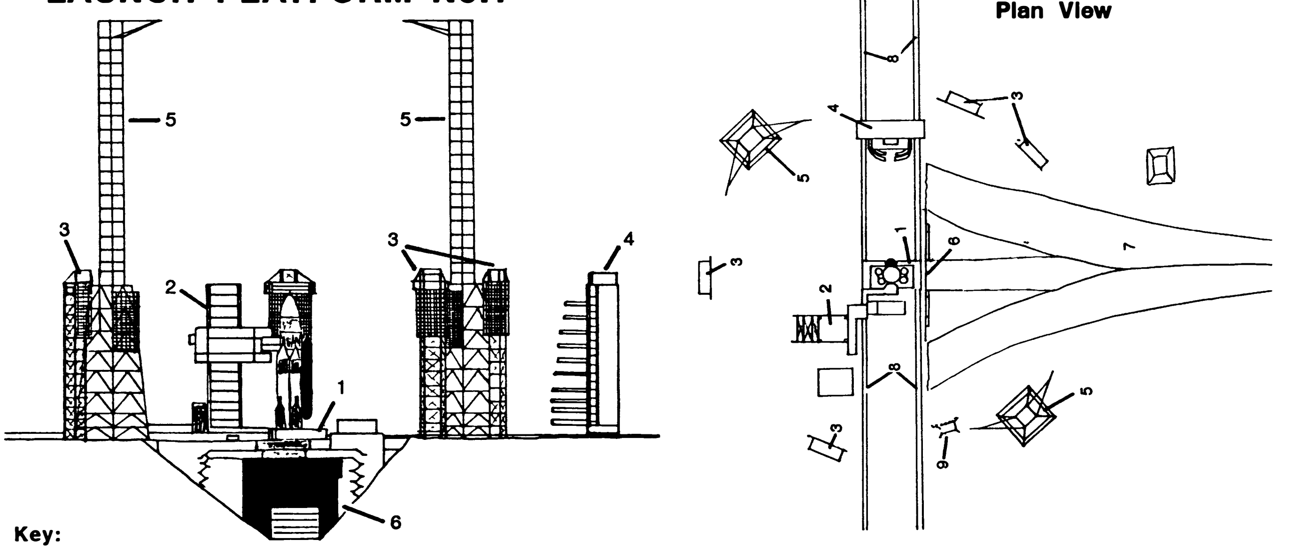
Launch Facilities

Several kilometres away and within sight of the technical zone is the Energia/Shuttle launch complex. There are three launch pads: Platforms 2 and 3 are for Energia/Shuttle launches; the third pad, Platform 1, was used for the inaugural launch of Energia on May 15, 1987 and is only used for non-Shuttle payloads and experimental work.

The two platforms of the Energia/Shuttle complex are of a similar design. They consist of a concrete platform which the MLMU, supporting the launch vehicle, rests on. Three flame trenches set 120 degrees apart direct exhaust from Energia's 12 engines away from the platform. Umbilicals through the MLMU and an umbilical plate on the aft of the orbiter, connect the vehicle with the launch pad services.

Two fixed service towers, about 64 m high are set either side of the launch vehicle and provide gantries for fuel and oxidizer connections. The service tower to the left of the launch vehicle supports a gantry for three liquid hydrogen tank vent connections set in the Energia's central core intertank structure between the liquid oxygen and liquid hydrogen tanks. The left-hand service tower also supports the orbiter access arm for cosmonauts to enter the vehicle through its side hatch. Running from the access arm are two pipes about 3 m in diameter, these lead to an underground bunker. The lower pipe is steeper and provides an emergency escape chute in the event of a fire or another emergency. To board the orbiter the crew ride on special trolleys up the top, less steep, pipe and enter a white room which is part of the access arm. To escape in an emergency they board the trolleys and take the steeper route to the bunker. The escape is reported to take about 15 seconds. Measuring the distance that the bunker is situated from the platform (about 130 m away) and allowing time for deceleration towards the bunker, the trolleys must travel at over 8 m per second. The crew access arm also carries umbilicals responsible for ensur-

LAUNCH PLATFORM No.1



Key:
1. Concrete launch platform
2. Fixed service tower
3. Floodlight towers
4. Mobile service structure
5. Lightning protection towers
6. Flame trench
7. V shaped channel
8. Railway tracks
9. Small floodlight tower

ing the gyroscopes in the orbiters are set correctly.

In addition to the fixed towers the two Energia/Shuttle platforms each have a rotating service tower which run on a circular railway tracks and carry gantries to enclose the orbiter for maintenance. The rotating tower on platform 2, which was used for the launch of Buran, is about 100 m tall, while the rotating tower on Platform 3 is of a similar height to the fixed towers. The taller rotating tower was originally used to support the Soviet manned lunar booster [6].

Surrounding the platforms are four large floodlight towers and two 225 m high lightning protection towers which also support floodlights. Double railway tracks run either side of the centre flame trench for the delivery of the launch vehicle to the pad. The Transporter/Erector rides over the flame trench as it approaches the pad.

Water reservoirs that supply the launch platform sound suppression and cooling system are located either side of the fixed towers. During launch huge pipes channel the water to spray nozzles which send thousands of litres of water onto the launch platform during launch.

The third launch pad, Platform 1, is of a different design to Platforms 2 and 3, with a single fixed service tower and one huge flame trench 40 m deep. There is no rotating service tower, a special mobile service structure, running on straight railway tracks, is used instead. The mobile structure has multiple work platforms which surround the launch vehicle and payload. The structure is withdrawn to a safe distance before launch.

The concrete launch platform is of a similar design to the two other platforms. Again, there are four large floodlight towers and two 225 m lightning towers surrounding the pad area.

The main feature of Platform 1 is the huge V shaped channel leading from the flame trench. This can easily be seen in satellite photographs of the area as a triangular feature. The launch complex was originally constructed for use as a test stand but was later developed for actual launches.

The Jubilee Aerodrome

Situated 12 km from the Energia/Shuttle launch complex is the Jubilee Aerodrome where the orbiters land after returning from orbit. It was also used for test flights of the Soviet shuttle atmospheric test vehicle equipped with jet engines for take off under its own power.

The runway is 4,500 m long and 84 m wide and runs from a south westerly to north easterly direction. The runway is equipped with a system called Vimpel to permit fully automatic landing. This system consists of six distance measuring equipment units (DME), three located off each end of the runway. One is located along the centre line at the end of a 20 km track, the other two on either side at a distance of 50 km from the runway.

For the final approach and landing a scanning beam microwave landing system is used, along with MLS type precision distance measuring units located at both ends of the runway to permit a landing from either direction. For Buran's initial flight, the orbiter landed from a north easterly direction flying over the cosmodrome before turning to face the runway.

The runway is controlled by a Command Post Direction and Dispatching Building (OKPD) six storeys high. This building acts as mission control during the landing phase and operates with the Flight Control Centre at Kalinagrad near Moscow.

Besides the facilities mentioned already, the Soviets have also constructed enormous storage facilities for the thousands of tonnes of cryogenic propellants, gases and liquid fuels required for the Energia/Shuttle systems. These are located at various remote sites around the Cosmodrome.

To inter-connect the facilities tens of kilometres of new railway track and roads have been laid down. A launch control centre was also constructed with the latest Soviet computer technology.

Location and History of the Energia/Shuttle Facilities

Analysis of photographs taken from space and by journalists visiting Baikonur, have enabled a map to be prepared locating the Energia/Shuttle facilities. A short history of the facilities can be plotted by comparing satellite photographs taken over the years.

Map 1 - Based on a photograph taken by Landsat 1 on March 16, 1973 of the whole cosmodrome. The main base area and the launch complex for the Soviet manned lunar programme can be seen (at this time the pads were being mothballed after the cancellation of the project). The city of Leninsk is visible in the lower half of the map.

Map 2 - Based on a Landsat 3 photograph taken in the early 1980's. It shows the Technical Zone and the shuttle runway. The runway was reported to be under construction in 1978 [7]. An area of new constructions was also reported, although the resolution of the original image makes it difficult to identify. A large new development is visible to the north of the Technical Zone.

Map 3 - Illustrates the Technical Zone, launch Complex and Jubilee Aerodrome

and is based on a photograph taken during the 1983 Space Shuttle mission, STS-9. The photograph gave the first clear views of the launch complex in the new development area. Large constructions were also identified particularly a large rectangular building described by one report as a booster assembly building [8]. Another large building was visible nearby in the area of the Soyuz integration building and launch complex. A Soviet film of the Apollo Soyuz Test Project rollout in 1975 showed a horizontal assembly building about 244-253 m long used by the Soviet lunar project [9]. The author has identified this building as the large booster assembly building in the STS-9 photograph.

Map 4 - Illustrates the main base area, Energia/Shuttle Technical Zone and surrounding areas as it looks in 1989. The launch complex and main base area buildings are identified. The map was based on the Landsat image of the area published by the US company EOSAT and photographs taken by journalists visiting the Cosmodrome in 1988. What was previously thought to be the booster assembly building can now be identified as the Shuttle MIK. The building was probably built for assembly of the Soviet lunar booster in the mid-1960s. After the cancellation of the lunar programme it was converted for the up coming Buran shuttle programme which started in the mid-1970s. This would certainly explain the poor condition of the building's exterior, its new looking interior and its massive size. The nearby Energia core integration building almost certainly had similar origins.

Acknowledgement

The author would like to thank the following people for their help in compiling this article: Tim Furniss, Neville Kidger, Rex Hall and Phillip S. Clark.

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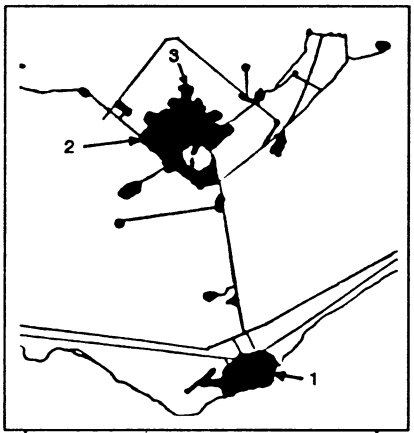
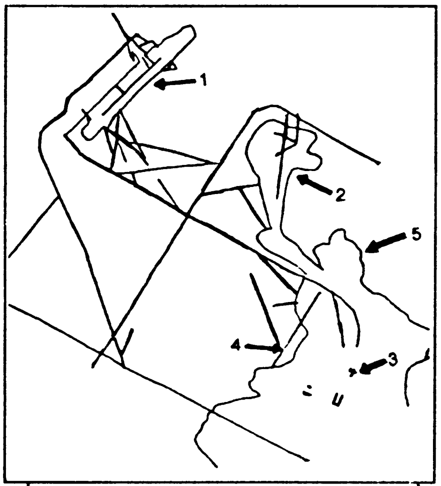
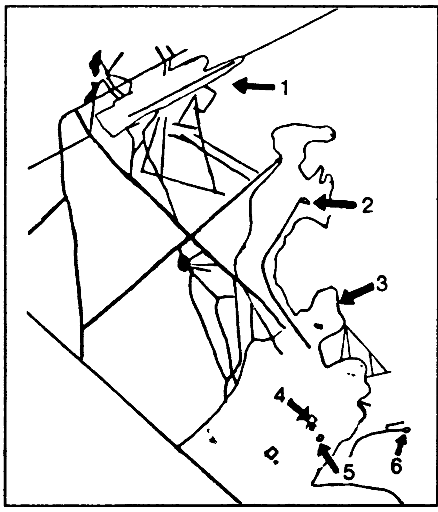


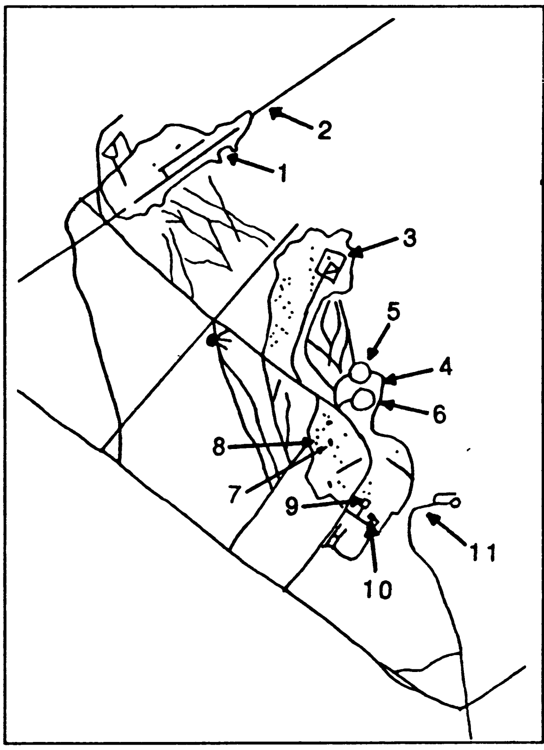
Map 1
1. City of Leninsk, 2. Main base area, 3. Launch complex, later to be used for Energia/shuttle.



Map 2
1. Shuttle landing runway (Jubilee Aerodrome), 2. New development area, 3. New constructions? 4. Technical zone, 5. Launch complex, later to be used for Energia/Shuttle.



Map 3
1. Jubilee Aerodrome, 2. New launch complex, 3. Energia/Shuttle launch complex, 4. Booster assembly building? 5. Another large assembly building, 6. Soyuz launch complex.
Lines show roads, railway lines, pipelines and powerlines.

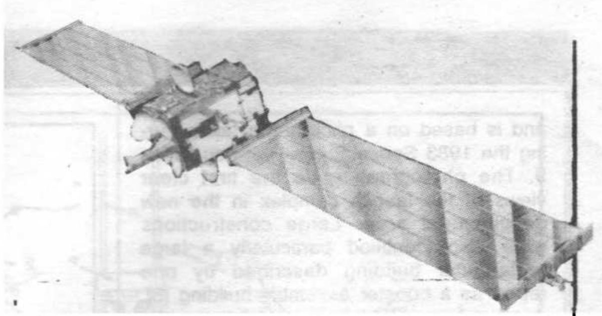


Map 4
1. Jubilee Aerodrome
2. 20 km track
3. Launch Platform No.1
4. Energia/Shuttle complex
5. Launch Platform No.2
6. Launch Platform No.3
7. Shuttle Checkout Building
8. Vibration Test Facility
9. Shuttle MIK
10. Energia Core Integration Building
11. Yuri Gagarin Launch Complex (Soyuz/Progress)

Lines show roads, railways, pipelines and powerlines. The Energia MIK is not identified due to the lack of information regarding its exact location. Although it is known to be in the same area as the Checkout Building, set further towards the runway and new launch complex.

OLYMPUS

A Giant Amongst Satellites



AT 21.14 local time on July 11 flight V32 lifted off from the Guiana Space Centre in Kourou, French Guiana. It was both an end and a beginning: the flight of the last Ariane 3 rocket and the launch of Olympus 1, the world's largest 3-axis stabilised civil communications satellite. Twenty minutes after launch, separation from the launcher occurred; the apogee engine was fired 36 hours later and the European Space Agency's technology demonstration satellite began to move towards its final destination at 19 degrees West.

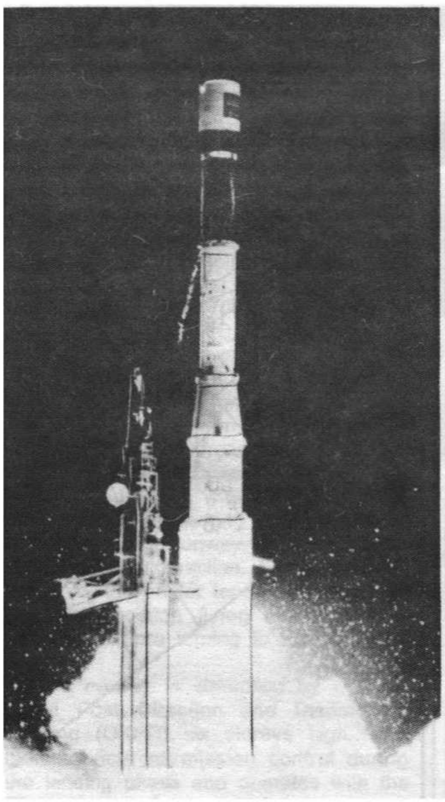
By Deborah Smith
British Aerospace

Olympus can claim a number of firsts in its field. It is the first civil communications satellite to have a microprocessor central electronics unit, which can be reprogrammed in orbit by ground control; it is the first European satellite to utilise the 20/30 GHz frequency band; and it carries the most powerful TV direct broadcast system ever flown. It also employs a beacon system to provide highly accurate pointing for an antenna in the direct broadcast television payload. It is unusual in being 3-axis stabilised in transfer orbit, unfurling its solar arrays after separation from Ariane. This is possible because the Liquid Apogee Engine (LAE), which is fired following the array deployment, provides only low thrust to propel the spacecraft towards its final orbit location. One advantage of a 3-axis stabilised transfer orbit is that it enables the spacecraft to carry top-heavy payloads which would destabilise a satellite in the more conventional spinning transfer orbit.

The Olympus concept originated from an ESA study in 1979, which showed a need for a new class of large multipurpose communications satellites. Following project definition studies, the development programme commenced in 1982, led by British Aerospace, with principal subcontractors Selenia Spazio and Aeritalia of Italy, Spar Aerospace of Canada and Fokker of the Netherlands. The aims of the project were twofold: to develop a high-powered platform able to meet future mission requirements and to promote new payload hardware, thus stimulating both the market and potential users. The success of the latter aim is amply illustrated by the large number and variety of experiments planning to use Olympus, including broadcast organisations and educational institutions. So what does the satellite offer them?

Olympus carries four distinct payloads: high power Direct Broadcast (DBS), Specialised Services, Ka-band communications and a Ka-band propagation package. The DBS payload provides two channels at 12 GHz. One of these (TVB1) will establish a pre-operational service for Italy, whilst the second, operating through a spot beam which is fully steerable to any European country, will be used for international TV experiments. BBC Enterprises will be one of the major users, responsible for providing up to eight hours of prime time television on a daily basis. The Specialised Services payload operates at 12/14 GHz, and is designed for experiments in satellite switching and frequency reuse. It utilises five spot beams which are steerable as a block, leading the way towards the multi-spot beam payloads of the next decade. Applications include tele-education, videoconferencing and data distribution, with experiments planned by a number of educational institutions. The Ka-band payload, which provides two small independently steerable spot beams, will be used for experiments at 20/30 GHz in videoconferencing (point-to-point and multipoint), tele-education and low speed data for business applications. ESA will use the payload for data relay experiments to and from the Eureca orbiting scientific platform, to be launched in mid-1991. Use of 20/30 GHz avoids further congestion at Ku-band, but the extent of the atmospheric attenuation affecting signals at these frequencies requires investigation. The fourth payload comprises three beacons which will be used for propagation research (at 20 and 30 GHz, in conjunction with the Ka-band payload experiments) and antenna pointing (12 GHz). In addition to these communications payloads, Olympus carries a highly sensitive vibration monitor. This will collect information on spacecraft disturbances which could affect the pointing of laser beams, to be used in operating systems in the future such as the Data Relay Satellite.

Ariane V32 blasts off carrying Olympus.
Arianespace



To support and power these payloads requires a large and powerful satellite. Olympus 1 has an on-station mass at the beginning of life of 1,550 kg and measures over 25.6 m (84 ft) from tip to tip of its flexible solar arrays. These arrays are deployed in three phases:

- The array assemblies are moved away from the walls on an elevation arm and canister assembly
- A motor-driven Astromast is used to extend the flexible blanket
- At full deployment the stretched substrate is kept under the correct tension by a tip tension mechanism

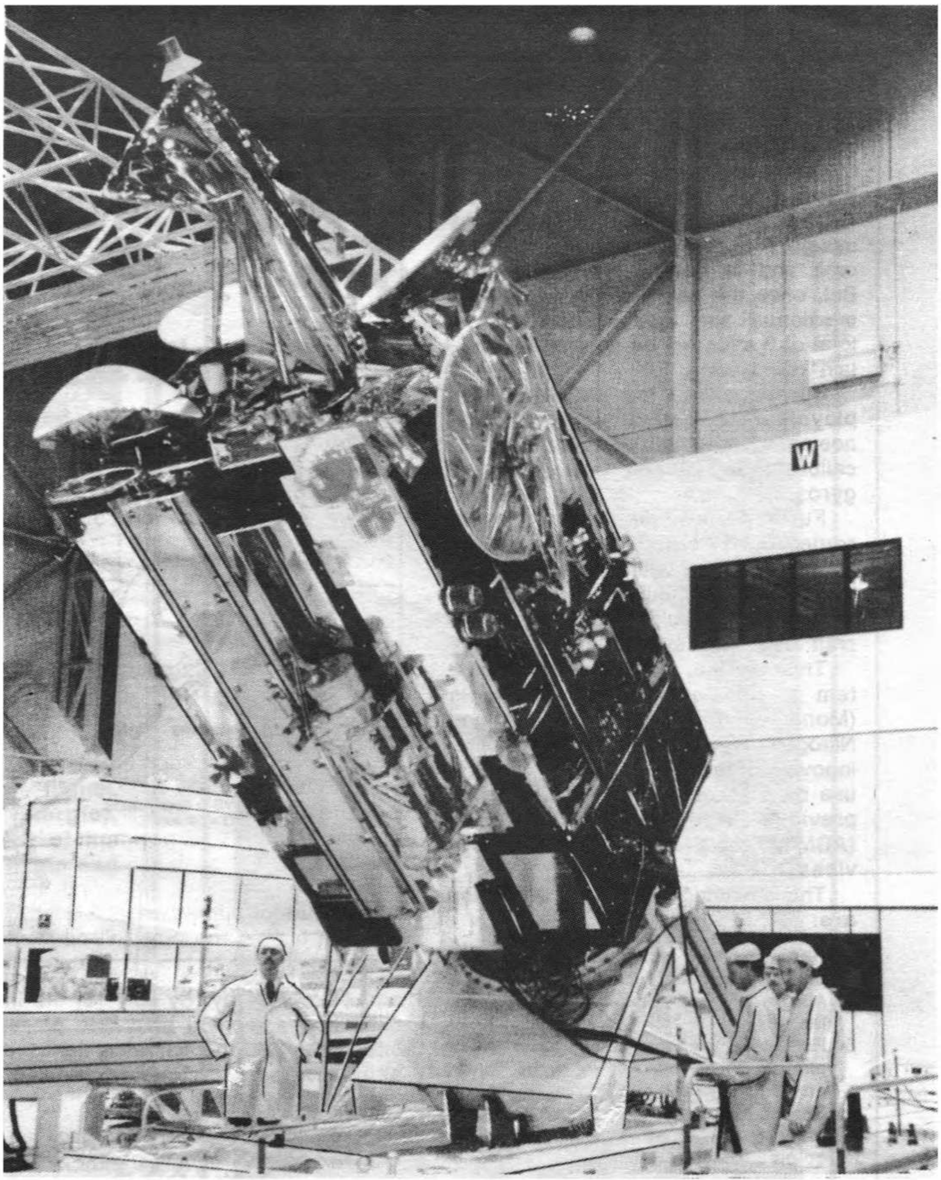
A total equinox power of 3.6 kW is supplied at the end of life. To provide power during eclipse periods, one nickel-cadmium and one nickel-hydrogen battery are carried. For future missions which may require higher powers, the arrays are capable of providing up to 7.7 kW of power and up to four batteries can be accommodated.

The spacecraft is 3-axis stabilised, with a zero momentum attitude control system employing reaction wheels on

each of three axes. It is tolerant to inertia changes resulting from varying array sizes and other mission-specific mass changes, requiring modification only to the software of the microprocessor-driven control electronics unit. This unit controls the reaction wheels and reaction control thrusters. Both the thrusters and the LAE are powered by the combined propulsion system, which uses monomethylhydrazine and nitrogen tetroxide. The structure is manufactured from conventional materials. Future developments could include stretching the platform to fully exploit the 4,200 kg GTO mass capability of Ariane 4.

The development of the Olympus platform resulted from a perceived trend towards larger and more powerful communications satellites. Since the initial studies were carried out the market has been sluggish, largely due to the Challenger disaster and subsequent expendable launch vehicle problems. Additionally, manufacturers and operators have been slow to adopt new technologies. However this situation is now changing, as exemplified by the manufacture and launch of satellites such as TV-SAT (German TV) and Superbird (Japanese TV). Current development of High Definition Television (HDTV) systems will require high power communications satellites and the need for high power will also be a prerequisite for any pan-European direct broadcast satellite with a large number of spot beams, the next logical step from the current generation of national DBS satellites. The ability of Olympus to accommodate large antennas also makes it a suitable platform to provide land mobile services. Moving away from the field of telecommunications, studies have been carried out on the use of the platform for the Canadian Earth observation satellite Radarsat.

On August 3, Olympus 1 arrived at its correct geostationary orbit location. Commissioning and in-orbit testing will continue until mid-October under the control of the European Space Operations Centre (ESOC) at Darmstadt. Operations will then be transferred to the ESA ground station at Fucino in Italy, and the satellite handed over to its many eager users. The aim of producing a high power communications platform has been fulfilled, resulting in considerable technology development in the space Industries of the countries participating in the programme. It remains to be seen how successful the satellite will be in developing new services, but given ESA's proven track record in promoting progress from research and development to operational satellite systems, the future of Olympus looks bright.



Olympus during integration and test. *BAe*

Olympus In Orbit

THE ESA spacecraft Olympus was launched from the ESA launch site at Kourou, French Guinea on July 12, at 00:14:03 (all times GMT). The powered flight of Ariane and the subsequent separation sequence was nominal and Olympus separated from the launch vehicle at 00:34. At 00:48 the flight Control computers at European Space Operations Centre (ESOC) in Darmstadt, West Germany, began to receive the Telemetry data from the ESTRACK station in Malindi, Kenya and the mission of Olympus was underway.

By D. E. B. Wilkins

Olympus Flight Operations Director

At 00:52 the Perth, West Australia station acquired the Olympus signal and for the next ten hours dual coverage from Perth and Malindi stations was provided to the ESOC OCC.

The first significant event in the mission occurred at 01:20 when the command sequence to deploy the very large solar arrays was initiated by ESOC OCC, (Operations Control Centre). These arrays are the first of their type to be deployed by ESA in space and are more than 10 metres long. The total length from tip to tip across the spacecraft is over 25 metres.

The deployment of the array is accomplished by means of two motors which drive the "astro-mast" at each side of the spacecraft out at a speed of 20 millimetres/sec. This mast, in turn, carries the "concertina-ed" array out to its full length of ten metres.

In the event the array extension command was initiated at 01:03 and by 02:07 full power of 4.1 kWs was

Continued overleaf

being delivered by the arrays to the Olympus electronic systems. Only a fraction of this power would be needed during the early stages of the mission in Geostationary transfer orbit and in near synchronous orbit. But, once the payload has been commissioned and fully switched on, a total of 3 kWs will be needed to maintain full service.

Subsequent to the solar array deployment a series of slew manoeuvres were conducted in order to calibrate and adjust the spacecraft gyros.

Further slew manoeuvres were carried out in order to align Olympus to the optimum attitude required for ignition of the Liquid Apogee Engine (LAE) which would place the spacecraft into near synchronous orbit.

This engine, a bi-propellant system using liquid hypergolic fuels (Monomethyl Hydrazine (MMH) and Nitrogen Tetroxide (NTO), is another innovation for ESA. This is the first use by ESA of such an engine as all previous Apogee Boost Motors (ABM's) have been solid-fuel devices.

The advantages of such an engine are:

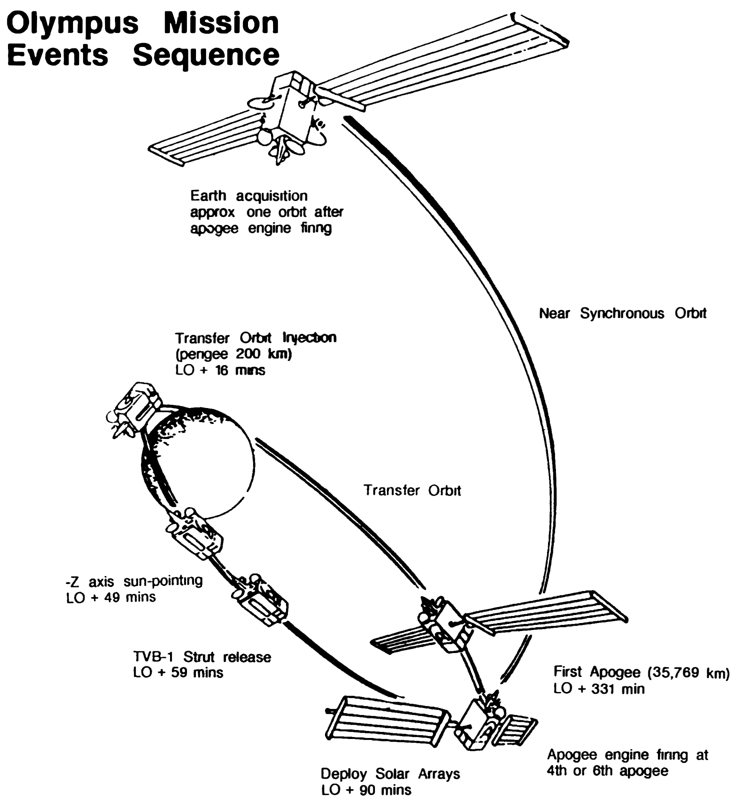
1. Relatively high performance when compared to solids.
2. Ability to flight test hardware before launch.
3. Relatively low acceleration rates which provide spacecraft with a more benign environment.
4. Should an anomaly occur after ignition, the engine can be shut down by telecommand.

The mission planning for Olympus required a continuous burn of the LAE and at the fourth Apogee on July 13, at 12:30:22 the command sequence was uplinked to Olympus via the Villafranca TS-1 tracking station.

The large (495 newton) engine fired as planned for a total of 103.5 minutes, injecting Olympus into a circular near synchronous orbit. During the LAE firing some 1,000 kgs of fuel and oxidizer were expended. Subsequent to the manoeuvre, orbit determination revealed that the spacecraft sub-satellite position was drifting from 28 deg W Long (where the LAE was fired) towards the East at about 14 deg/day. This drift rate was higher than expected and resulted from slightly lower than expected performance of the LAE (actual thrust was about 2-3% less).

On July 15, 1989, the first station acquisition manoeuvre to inhibit the easterly drift of Olympus and to establish a westerly drift towards the on-station position was initiated. This manoeuvre lasted nearly 50 minutes beginning at 10:54 and resulted in a slight westerly drift of Olympus of about 0.4 deg/day. By July 18, the In-Orbit commissioning plan was placed into effect and the following series of activities were conducted between then and the end of July:

Olympus Mission Events Sequence



July 18	Start Propellant Gauging.
July 19	Check Infrared Earth Sensor characteristics.
July 20	Check of spacecraft microprocessors.
July 22	Thermal tests, propellant gauging heaters on.
July 25	Thermal tests, end propellant gauging. Perform E/W station acquisition manoeuvre.
July 26/27	Power subsystem tests.
July 28	TT&C subsystem tests. Perform N/S station acquisition manoeuvre.

The manoeuvre of July 25, increased the drift rate of Olympus so that the satellite arrived at 19 deg. W. Long on August 3, 1989 where it will be maintained on station throughout its planned lifetime.

Payload commissioning then began to fully test the communications payload before operations begin in October 1989.

The Olympus payload consists of four separate sub-systems each with its own antenna:

- A 12/20/30 GHz Propagation Package to complement and verify propagation statistics in the higher frequency range.
- A 12/14 GHz Specialised Services payload for advanced communications between small Earth terminals.
- A Direct Broadcast Payload with two channels, one for pre-operational Italian use and the other for European use.
- A 20/30 GHz Communications Payload for point-to-point and multi-point teleconference and other experimental applications.

During August and September the following commissioning and testing was scheduled:

August 1	Radio-frequency sensing and Antenna pointing mechanism tests.
August 2	Propagation payload tests.
August 3	20/30 GHz Payload tests.
August 4	TV Broadcast Payload test.
August 7/8	Specialised Services Payload tests.
August 14	Begin In-Orbit testing of complete communications payload (approx, 6 weeks) using In-Orbit Test station at Redu, Belgium and other European Earth stations.

During October dual operations between the OCC at ESOC and the On-Orbit Control Centre in Fucino, Italy will take place, leading to a handover from ESOC to Fucino on or about October 10, 1989. The Olympus Control Centre at Fucino will be responsible for the mission control of Olympus until mission termination. Planned lifetime of Olympus is not less than 5 years.

This article has been prepared using information contained in ESA reports and the ESA Olympus 1 Press Kit.

ISSN 0038-6340

December 1989 US$3.00 £1.25

Spaceflight

The International Magazine of Space and Astronautics

Shuttle

- "HERE TO STAY" SAYS NASA
- LDEF RECOVERY MISSION
- JUPITER PROBE LAUNCH
- 1990 LAUNCH SCHEDULE

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Vol.31
No.12

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Spaceflight is distributed in the UK and overseas through newsagents by AGB Impress, Cloister Court, 22-26 Farringdon Lane, London, EC1R 3AU. Tel: 01-253 3135.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery. ***Spaceflight*** binders (holds 12 issues) are available at £6.00 (US$11.00), inclusive of surface mail delivery.

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Published monthly by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by JWL, Ltd., Aylesbury, Buckinghamshire, England.

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Spaceflight

The International Magazine of Space and Astronautics

Vol. 31 No.12 December 1989

FRONT COVER: Atlantis makes a perfect landing at Edwards Air Force Base on October 23, following her highly successful five day mission. See p 416 for a full report

Columbia's Race Agai

NASA is planning its most daring mission since the Challenger accident. This month the Space Shuttle Columbia will attempt to recover the Long Duration Exposure Facility (LDEF) before it reenters the atmosphere. Since the return to flight, Shuttle missions have been fairly routine satellite deployment flights, lasting four or five days. But with STS-32 NASA will attempt its most ambitious mission in years. Not only will the Shuttle crew deploy a communications satellite, they will also rendezvous with LDEF and place it in the payload bay, during a mission that will last ten days - possibly exceeding the record for the previous longest Shuttle mission.

The launch of STS-32 is set for December 18 at 23:46 GMT. Onboard will be astronauts Daniel Brandenstien, James Wetherbee, Bonnie Dunbar, Marsha Ivins and David Low.

The Crew

Daniel Brandenstien, is Commander for STS-32. He has flown on two Shuttle missions STS-8 and STS 51-G. James Wetherbee, a Group 10 astronaut, is pilot and will be making his first space flight. Mission Specialists for STS-32 include two women: Bonnie Dunbar and Marsha Ivins. Dunbar will be making her second Shuttle mission - she previously flew aboard the seven day Spacelab mission STS 61-A. Marsha Ivins is also a Group 10 astronaut and will be making her first space flight. The third Mission Specialist is David Low. Again a Group 10 astronaut, Low will also be on his first Shuttle mission.

A Close Call for Columbia

As reported in last month's ***Spaceflight*** the orbiter Columbia was doused with water when the Orbiter Processing Facility (OPF) fire sprinkler system was accidently activated. The water ran for seven to ten minutes before it was shut-off.

Had the payload bay doors been open at the time water would have flooded into the orbiter's mid-fuselage and possibly into the wing cavities. The weight of the water alone could have caused severe structural damage. Fortunately the payload bay doors had been closed several days before.

Despite the water incident NASA still expects to meet the December 18 launch date. "We are recovering very well," Columbia's acting Flow Director Larry Ellis, told ***Spaceflight.***

"[After the incident] we inspected all areas of the vehicle and mapped out anywhere there was water. We also inspected all areas of the OPF," Ellis said. "There was water in the body flap, which had been sitting on a bench after it had been removed following the last flight. We inspected it thoroughly and cleaned up the water - no damage at all. We were fortunate."

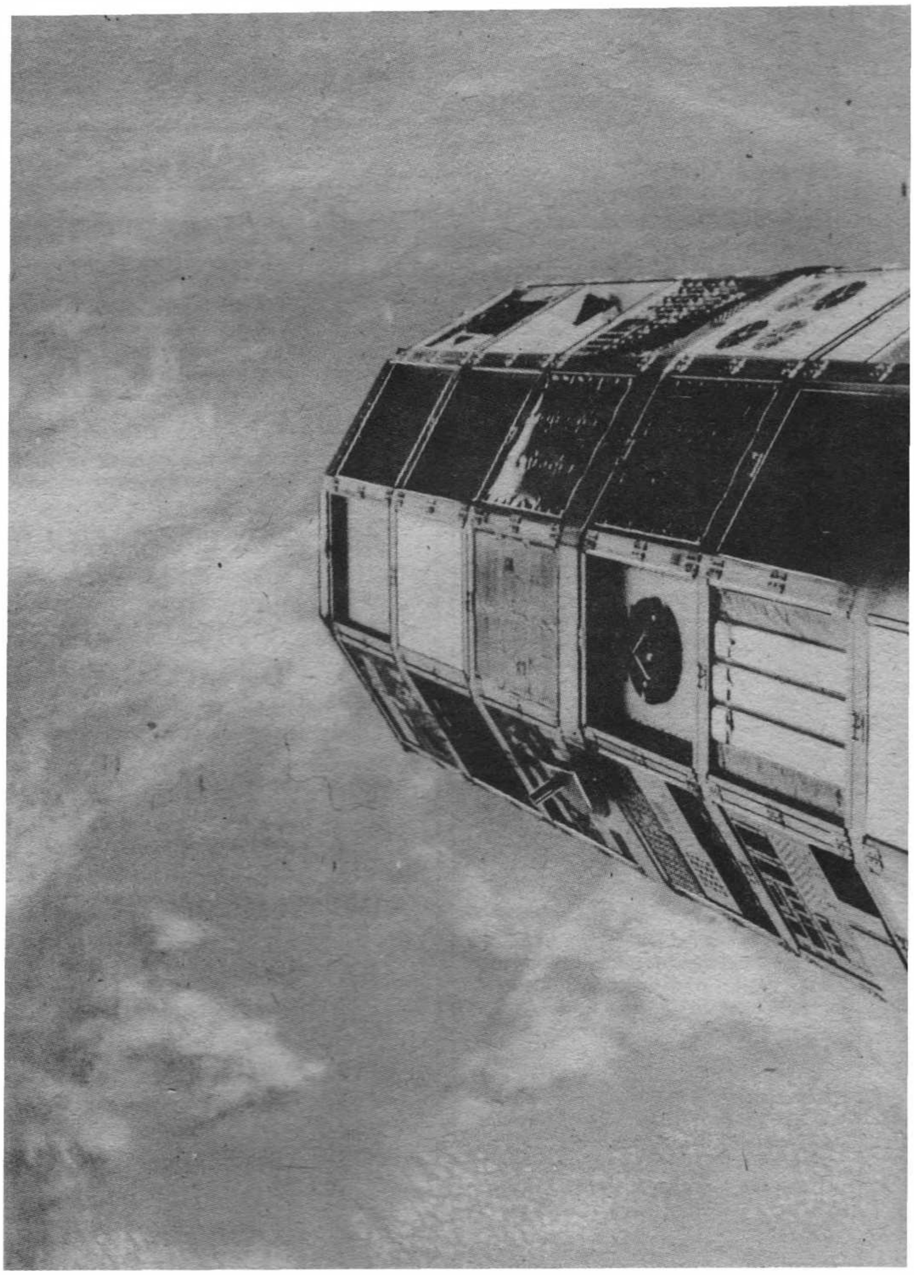
A number of thermal protection blankets had to be replaced. "Most of the blankets that had water in them were off the vehicle on a bench waiting to be installed," Ellis said.

The Reinforced Carbon Carbon panels that protect the orbiter's wing leading edges had obsorbed water and were removed and baked to drive out the moisture.

Launch Preparations

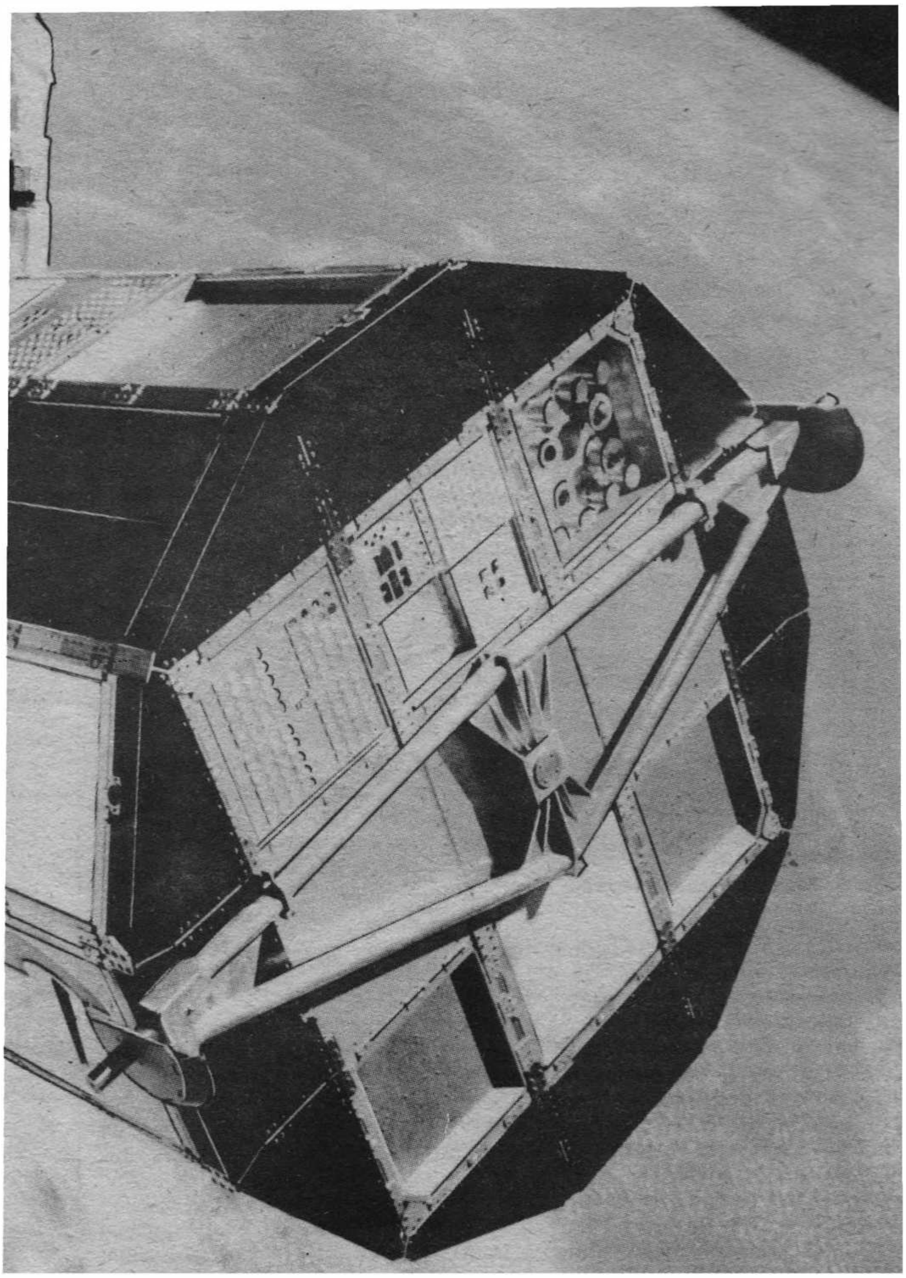
Columbia had returned to KSC in excellent condition. "We had the smallest number of inflight anomolies since the return to flight," Ellis said.

However there was some damage to the orbiter's Thermal Protection System. Apparently the secret DoD STS-28 mission had ended with a high angle of attack during reentry. This



LDEF on the end of the RMS just prior to it deployment on STS 41-C in April 1984.

ıst Time to Save LDEF



NASA

caused some overheating around the orbiter's rear underside charring a number of tile gap fillers, which will have to be replaced. Larry Ellis believed this was a minor concern. "Other than the overheating, it was a pretty nominal flight from the stand point of the Thermal Protection System," he said.

The main engines were removed from the orbiter for examination and were reinstalled on October 5 to 8. A problem with a main engine pump was noted but Larry Ellis said if the pump required replacement the launch date would not be affected.

The 15.2 metre Remote Manipulator System (RMS) arm was installed in Columbia's payload bay on October 18. The arm will be used to recover LDEF. This will be the first civilian Shuttle mission to carry the RMS since the Challenger accident.

The preparations for STS-32 differed from normal, because five additional liquid oxygen and liquid hydrogen tanks were installed beneath the orbiter's payload bay. The tanks will supply oxygen for breathing air and reactants for the orbiter's fuel cells which generate the onboard electricity. The additional tanks were installed because Columbia's December mission will last ten days and require extra supplies.

Columbia is due to be transferred to the OPF on November 13 and will be rolled out to launch Pad 39A on November 22. This will mark the first launch from Pad A since STS 61-C in January 1986.

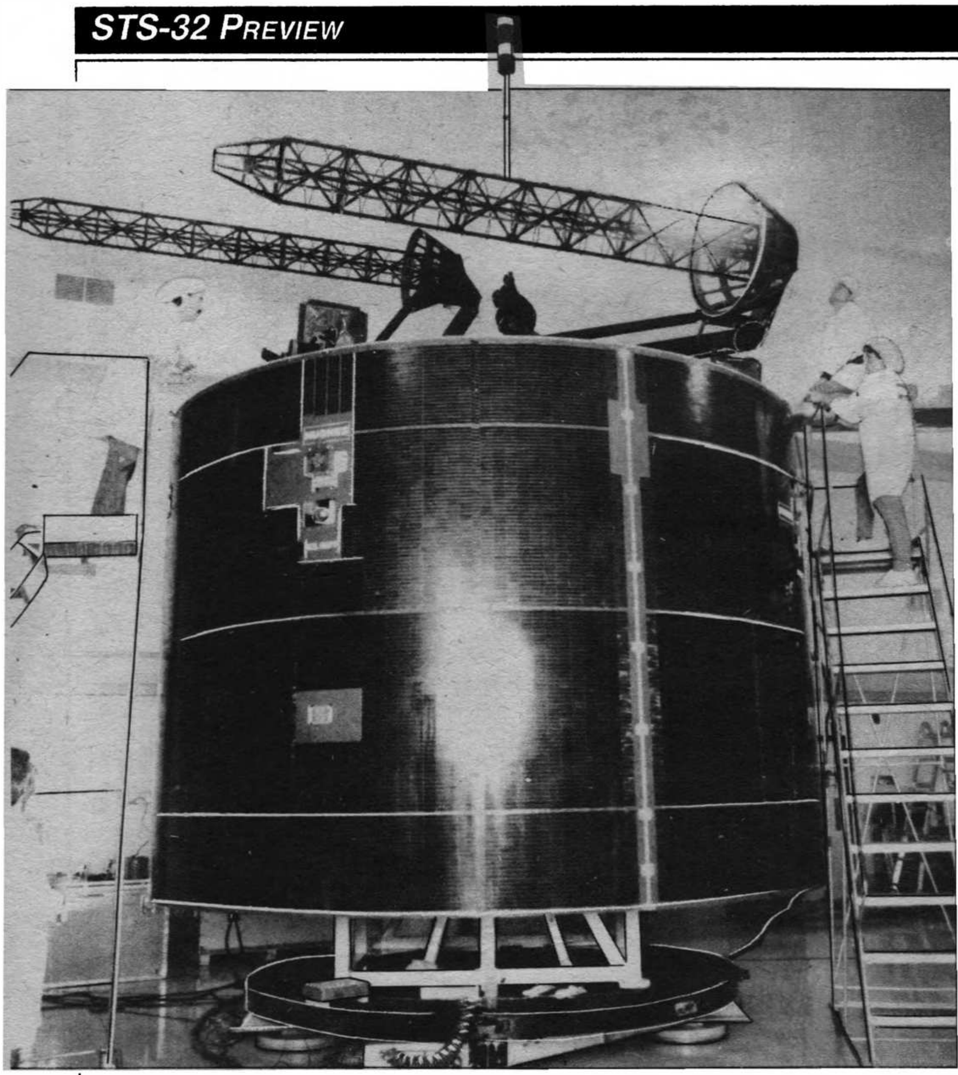
Syncom IV-05 Deployment

The Syncom IV series were the first satellites designed exclusively for launch aboard the Space Shuttle. It was for this reason Syncom IV-05 could not be transferred to an expendable rocket after the Challenger accident. The satellite will form part of the worldwide Leasat communications system for the US DoD. The satellites are also known as Leasats. They are primarily used by the US Navy to supplement the Fltsatcom network. The satellites are leased from Hughes Communications Services Inc., a subsidiary of Hughes Aircraft.

Four Leasats were deployed by the Shuttle prior to the Challenger accident, but the satellite has an unlucky history. Leasat 2 was launched on STS 41-D. However in September 1985 its wide-band channel failed and the US Navy refused to pay for the lost capacity, in accordance with the lease contract. Leasat 1 was deployed by STS 51-A and remains the only fully operational satellite in its series. Leasat 3 was deployed on STS 51-D, but its apogee boost motor did not fire when its timer malfunctioned. The 51-D crew attempted to activate the satellite with a 'fly-swat' at the end of the Shuttle's arm but this failed. The satellite was later repaired during mission STS 51-I in August 1985 and successfully reached geostationary orbit. Ironically, Leasat 4, deployed earlier during mission 51-I, failed in geostationary orbit and was written off. Hughes hopes Syncom IV-05 or Leasat 5 as it will be known, will have better luck than some of its predecessors.

The satellite will be installed in Columbia's payload bay laying on its side, with its retracted antenna pointing towards the nose of the orbiter and its propulsion system pointing towards the back. Five trunnions are used to attach the satellite's supporting cradle to the Shuttle. Five similarly located points are used to attach the spacecraft to the cradle.

A unique feature of the Leasat series is they contain their own unique upper stage to transfer them from the Shuttle deploy orbit of about 190 nm to a geostationary orbit of 35,000 km.



The Syncom satellite undergoes an antenna deployment test in the Astro-Tech satellite processing facilitiy near Titusville, Florida *NASA*

All other satellites deployed from the Shuttle require a separate upper stage to accomplish this.

Ejection of the spacecraft from the Shuttle is initiated when locking pins at the four contact points are retracted. An explosive device then releases a spring that ejects the spacecraft in a 'frisbee' motion. This gives the satellite its separation velocity and stability during the 45 minute coast period between deployment and ignition of the perigee kick motor. The satellite separates from the Shuttle at a velocity of 0.7 m per second and a spin rate of about two rpm.

Forty-five minutes after deploy the satellite's solid rocket motor is ignited and raises the apogee to 9,545 miles. Two liquid fuel engines are used to augment the velocity on successive perigee transits, to circularise the orbit and to align the inclination with the Equator.

LDEF Retrieval

LDEF was released from the Space Shuttle Challenger in April 1984 during the STS 41-C mission. LDEF carries 57 experiments to examine the effects of space flight on various samples over a long duration. The experiments also include a UK developed experiment to measure micrometeoroid impacts and a container of several million seeds which will be compared with a similar number of seeds kept on Earth. Other LDEF experiments range from materials to medicine to astrophysics.

It was originally intended to retrieve LDEF on STS 51-D in February 1985. As the Shuttle schedule slipped the retrieval was removed from 51-D. It finally looked like LDEF would be returned on mission STS 61-I, scheduled for September 1986 but the Challenger accident put a stop to that. Now after five and a half years in orbit LDEF is scheduled to be retrieved on STS-32. However, LDEF's orbit has decayed and NASA faces a race against time to recover the spacecraft.

"We have a recent assessment date of as early as February 9, 1990 for LDEF to fall to Earth," NASA Public Affairs Officer, Pat Philips told ***Spaceflight.*** There reaches a point where the Shuttle can no longer attempt a recovery of LDEF due to the orbiter's minimum altitude restriction of about 130 nm.

"The first week in February could be the cut off point," Philips said. "But there are so many variables at this point, it is very difficult to say exactly when. The estimates keep changing."

If Columbia can reach LDEF in time, the shuttle crew will attempt to retrieve the experiment three days into the flight.

"We are going to approach LDEF, flying in relationship to Earth, upside down and backwards," explained Philips. "The Shuttle will be flying above it and will gradually drop down closer until the point where the Shuttle is parallel to the Earth and perpendicular to LDEF."

Mission Specialist Bonnie Dunber will use the Canadian built RMS to reach out and latch the arm on to one of LDEF's primary grapple point located half way along the side of the spacecraft. If the arm fails to connect here Dunbar will try to use the back-up grapple point located on the otherside of LDEF. Once the RMS has a firm grip the crew will begin a photographic survey of LDEF. The arm will turn the spacecraft as required while the crew take pictures through the aft flight deck windows. The operation will produce a record of the experiments' condition before LDEF enters the payload bay.

The next step is to place LDEF in Columbia's payload bay. There are five trunnions to attach the spacecraft to the payload bay fittings. Each trunnion must latch successfully before LDEF can be returned to Earth.

The LDEF experiments must be protected from contamination after Columbia's landing:

"One of the first measures they are taking, is to leave it in the orbiter instead of taking it out at Edwards and putting it into transportation," said Philips. The payload bay will remain sealed until the orbiter enters the OPF, which has a clean room facility. It is here that the LDEF will be removed from Columbia, placed into a special transport and taken to the clean room at the Operations and Checkout Building.

A working group will be formed to take an overall look at the entire LDEF. Then the individual experiments will be released to the various investigators.

Because of LDEF's extended stay in space the actual structure of the LDEF spacecraft will be of interest to scientists. It was originally planned to reuse the LDEF structure every 18 months but NASA has yet to schedule a second LDEF mission.

"Right now we are going to bring it home. Take a look at it and see what kind of shape it is in," Philips said.

Shuttle is Here to Stay Says NASA Deputy Administrator

In an exclusive interview with *Spaceflight* J.R. Thompson, NASA's Deputy Administrator, says he believes the Shuttle will be operational until 2010. He also calls for a fifth orbiter in case a further Shuttle is lost. Mr Thompson was interviewed at the Kennedy Space Center by *Spaceflight's* Assistant Editor *Steven Young* shortly before the launch of STS-34 carrying the Galileo Jupiter probe.

NASA Deputy Administrator, J.R. Thompson, is presented with an award by the STS-26 crew in recognition of his efforts in the return to flight of the Shuttle. *NASA*

What do you think is the biggest challenge facing NASA today?

I believe the biggest challenge is still in the Shuttle programme and it is to keep flying. We have had five successful launches since the Challenger accident. The Shuttle is a very unforgiving vehicle. It is designed with limited margins - it is a good design but a very high performance vehicle. There are some things we can do to build in even more margins. The Shuttle main engine and the Solid Rocket Booster are the two things that bother me most. But the biggest challenge is to keep the teams alert, not just for this launch of Galileo, but for the rest of the decade. That is going to be a real challenge.

What do you foresee as the next manned vehicle to replace the Shuttle?

We are still at the front end of the Shuttle programme. I believe the Shuttle will evolve in areas to become more robust and will be flying through to the year 2010. It is too early to start looking at a Shuttle-2 or whatever one wants to call it. I would capitalise on the Shuttle we already have and try to improve it. We should augment the manned Shuttle with an unmanned Shuttle, Shuttle-Cargo or Shuttle-C as it is called. That would be a very complementary launch vehicle set. I would call the development of Shuttle-C a 'go do' programme. We would use the same Solid Rocket Motors, the same External Tank, the same engines and replace the orbiter with a cargo module. There is some development work, but there is no new technology needed, it is a very straight forward project.

When would development of Shuttle-C begin?

I think Shuttle-C s highly desirable but its future depends on NASA stating a real need for it. Right now we have nothing on the manifest that would absolutely require it. But over the next couple of years we expect to see our way clear to start the development in a modest way. Maybe, by the mid to late 1990s, we will have the Shuttle-C capability.

The Office of Technology Assessment has called for NASA to have a fifth orbiter in case of a further accident. Is a another orbiter a realistic possibility?

I think it is. I would very much like to see us do it. We should be planning today for the next failure. I think the next failure is going to happen, it is just a matter of when. I think our flight rates are safe but space flight is a risky business. If we could get another orbiter started now we would be in pretty good shape for the next several years.

Do you think NASA can meet its present requirements with a fleet or three - soon to be four - orbiters?

We do not need a fifth orbiter to be able to fly the manifest we already have. We can do that with the four orbiters that we are going to have in a couple of years. But that assumes total success for the next decade and that is not the way space flight works and that is why we should be planning for the future and hedging bets against another failure. We need a fifth orbiter for that.

The Space Station project has suffered a number of budget cuts. How much of a blow is that to NASA?

We are probably not going to get everything on the Space Station we want. Our request for Fiscal Year '90 was about $2.05 billion. I am hopeful we will end up with about 85 to 90 per cent of that and, if that is the case, we will still have a very healthy, robust Space Station. Our primary drive now is to try and keep the Space Station on schedule and, if the money is going to be rather tight up front, try to accommodate that through the way we phase the programme and do not let it affect the initial launch date. That seems to be the course we are on. There is a lot more talk about instability in the programme than there really is. I think it is in good health. It is a good programme and we will go forward.

Are you leaving your options open so you can expand the Space Station to its original capabilities at a later date?

Yes. For example, power. By the late 1990s we will have the same power as we were planning six months ago. If we go back and look at the capabilities of first Skylab, then Spacelab and even Mir, the re-phased Space Station we are talking about has far more capabilities than any of those programmes. So we are going to have a very healthly Space Station.

Earlier this year we heard President Bush's announcement calling for NASA to draw up plans for a return to the Moon and then on to Mars. What exactly does this announcement mean for NASA?

We are in the process of laying out a programme to do it and putting into place the technology that will be re-

quired. We are right in the middle of what I would call an initial response. We have got a good effort. Of course, NASA is very excited about it. I would like to see us do it in such a way that it builds on what we already have. Once we have accomplished the lunar settlement, it will continue to build and will not retrench back, like Apollo did. If we structure the programme and think that way up front then we can make it happen.

What do you see as the future of the US manned space programme in the next century?

It will be a very dynamic future. I think the manned programme is always going to be the centre piece of the US space programme but that does not sell short the unmanned programme. We launched Magellan earlier this year and Galileo today. The Cosmic Background Explorer (COBE) is scheduled for November 1989, the Hubble Space Telescope in March 1990, followed by the Gamma X-Ray Observatory (GRO) in late spring/ early summer of 1990, Ulysses about a year from now. That is putting up science which will be up there collecting data beyond the year 2000. I think this will really be the golden era of space science.

NASA has been criticised by planetary scientists in the past for concentrating too much on the manned side of space flight. Have we seen the rebirth of the US planetary programme.

We are just coming off the heels of Voyager and are going to have Magellan, Galileo, Hubble, GRO and Ulysses. So it is going to be a very exciting time for space science.

So the NASA leadership places a lot of priority on its space science programmes?

Yes, a lot of priority. One area we haven't touched on yet is the Mission to Planet Earth. That is going to have a very high priority in the Bush Administration and within NASA as well.

Freedom - A Clearer Picture Emerges

Details of NASA's new configuration for Space Station Freedom are beginning to emerge. The Space Station was scaled down because of budget cuts and NASA's realisation that it had underestimated the costs of the project. A number of features planned for the station's initial construction phase have been postponed until after Permanent Manned Capability (PMC) is achieved.

Earlier this year NASA began to accept a cut in the Space Station budget was inevitable. To accommodate this NASA's Space Station Office established a task force to reexamine the plans for the initial Freedom configuration. The group was charged with lowering the development costs for the early 1990s, while keeping the project on schedule.

The Configuration and Budget Task Force, as they were officially known, met at NASA's Langley Research Center in Hampton, Virginia over a three week period in August. Their solution was to abandon or postpone some of the more ambitious Space Station features, while ensuring these features could be added after Freedom became operational, if the money became available.

One of the first tradeoffs the Task Force made was the propulsion system. It was decided to replace the costly hydrogen/ oxygen system with a hydrazine system. This lowered initial development costs but will increase logistics requirements, and costs, once the Space Station is operational. The original system used electrolysis to break down water into hydrogen and oxygen to fuel the station's thrusters (see *Spaceflight*, June 1989, p.189). The system offered lower costs once Freedom became operational. Excess water produced by the Space Shuttle's fuel cells could have been pumped across to the station's propulsion system each time an orbiter docked. "It's basically a free resupply," an engineer working on the hydrogen/oxygen system said. "We can save on the amount of propellants that have to be brought up to the station," and added "it can save a significant amount of money over the 30-year life of the programme."

Current estimates show the hydrazine system, now adopted by the project, will require 9,000 to 18,000 lbs of hydrazine each year. This is the equivalent of a quarter to half the payload capacity of a Shuttle each year.

However, by abandoning the rather complex oxygen/hydrogen system, 4 kW of power - intended for the electrolysis process - will be saved.

Another trade kept 'open' the oxygen and water loops of the Environmental Control and Life Support Systems until close to the completion of the station's assembly. The original design called for a closed-loop life support system, where water and oxygen are fully recycled. Depending on crew size, the change will require an additional 5,000 to 10,000 lb increase in logistics requirements to provide bottled breathable air until the loops are closed.

Another significant change to the programme was the reduction of the Freedom's EVA capabilities. The original plans included a specially designed space suit for Freedom operations, designed for easy in-orbit maintenance and requiring no prebreathe operations. The station was to be equipped with two airlocks. The second airlock would be a back-up to the first and a service area for the space suits.

The task force eliminated one airlock and made modifications to allow one of the station's resource nodes to serve as a backup airlock.

The new suits will be abandoned and the tried and tested Shuttle space suit used instead. All EVAs would be made from a docked Space Shuttle orbiter. EVAs from the Space Station would only be made in emergencies.

Other changes include:

- ☐ Reduced power of 37.5 kW (to be increased to full 75 kW once operational).
- ☐ Reduced crew size of four until after PMC.
- ☐ The onboard refrigerator/freezer will be delayed until power becomes available.
- ☐ Two of the Space Stations four nodes will not be fully outfitted until after PMC.
- ☐ Windows in the US Laboratory Module have been eliminated.
- ☐ The washer, dryer and dishwasher will be delayed until power becomes available.

Assembly Sequence

The major change to the Freedom assembly sequence was to reduce the number of Space Shuttle assembly missions to five per year until PMC. This resulted in a delay of launch of the European and Japanese modules. The task force conducted a study to determine how best to schedule the launch of the modules. The options were:

- ☐ After PMC, deliver
  - Additional 37.5 kW of power and thermal rejection
  - International modules and equipment
  - Data Management System (DMS) upgrades and crew of eight capability
- ☐ Before PMC, deliver
  - Additional 37.5 kW of power and thermal rejection
  - DMS upgrades and crew of eight capability

  After PMC, deliver
  - International modules and equipment
- ☐ After PMC, deliver
  - International modules and equipment
  - Additional 37.5 kW of power and thermal rejection
  - DMS upgrades and crew of eight capability

The third option offered the earliest launch of the international modules but would not allow their full use until the additional power, Data Management System, etc. were delivered.

The second option delivered the additional systems required for full use of the Japanese and European modules but provided the latest module launch date.

As a compromise it was decided to select the first option. The modules would be launched after the additional power and the heat rejection system had been added, but before the DMS upgrades and the eight crew capability.

The redesigned space station will achieve PMC on Space Station Shuttle Flight 12. The entire assembly sequence will take 29 Shuttle missions.

Would-be Astronauts Leave for Moscow

The race to become Britain's first astronaut is drawing to a close. The number of candidate has been reduced to four. The three men and one woman will now undergo final testing in the Soviet Union. By the end of November the final two candidates will begin their training at Star City.

The final four candidates for the 1991 Juno mission were revealed at a London press conference on November 5. They were: Gordon Brooks, Timothy Mace, Helen Sharman and Clive Smith, see biographical details below.

The search for Britain's first astronaut began in early July with a series of newspaper advertisements. More than 12,000 people applied. By the beginning of November the number was reduced to four.

Geoffrey Pattie, Chairman of Antequera Ltd, told the press conference. "We have come a very long way in a short time."

"We have managed in four months what it has taken other nations five, six or seven times as long," said Peter Howard, head of astronaut selection for the Juno project. "We have finished up with four candidates when some other countries have ended up with none at the end of this process."

Fifteen of the 16 astronaut candidates made it through the tests at the Institute of Aviation Medicine (IAM) in Farnborough.

"The candidates went through what I think is the most complex and the most exhaustive series of medical examinations ever carried out in this country," Peter Howard said.

The medical files and the results of the tests at IAM were presented to a delegation of Soviet doctors and space officials. In conjunction with their British colleagues; the Soviets selected the final four candidates.

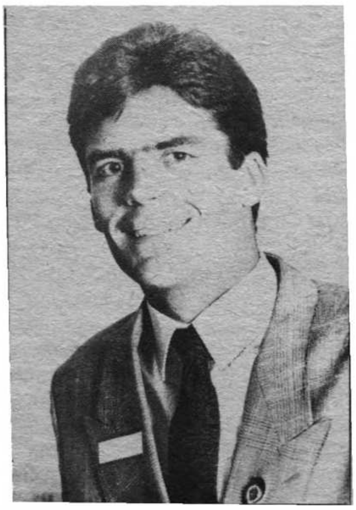
The four would-be astronauts arrived in Moscow on November 12, to undergo final medical examinations and tests conducted by an independent State Commission. On the basis of these tests the Soviets will place the candidates in order of preference.

When the candidates return to the UK around November 24/25, the Juno management will choose - based on the Soviet recommendations - the final two, who will return to Moscow on November 30 to begin training for the 1991 Anglo-Soviet mission.

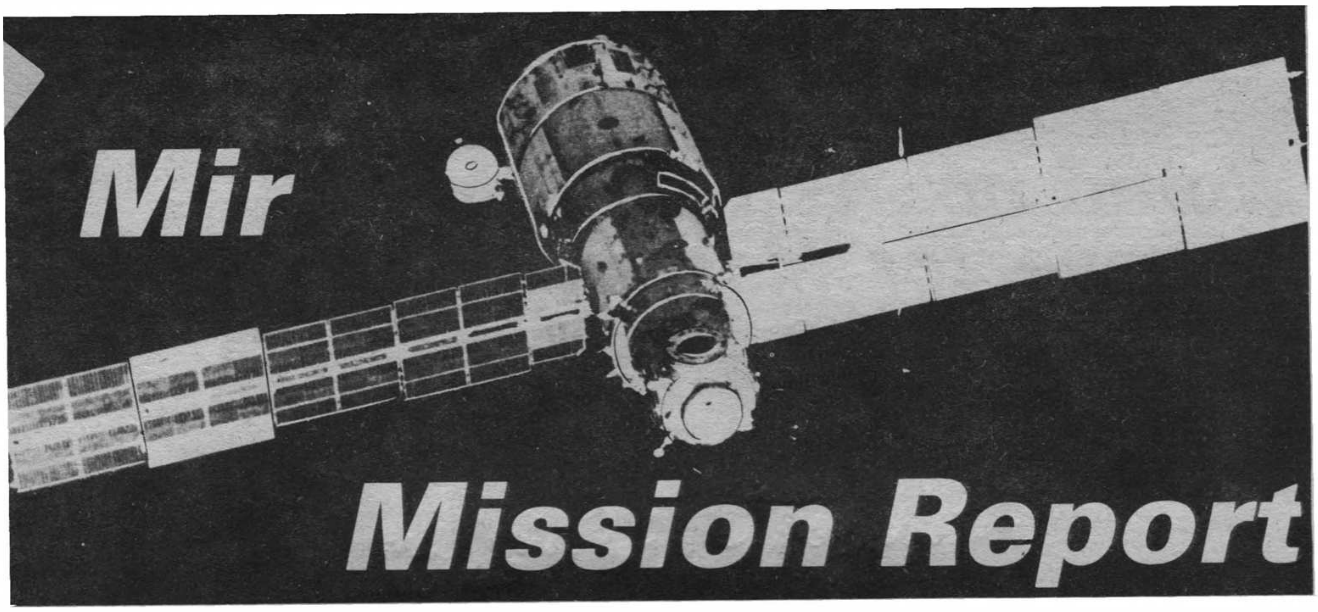
Gordon Brooks, 33, is a Royal Navy medical doctor and a veteran of the Falklands War. He lives in Gosport, Hampshire, with his wife, Christine, and four children - Helen, 7; Catriona, 5; Douglas, 3; and Donald, 1. He graduated from Dundee University in 1980 with a degree in medicine and entered the Navy as a medical officer. In 1982, in the Falklands, he survived the sinking of the Atlantic Surveyor. He is a keen deep sea diver and swimmer, and sails his own 23ft yacht. In 1966, aged 10, Gordon wrote to the Ministry of Aviation volunteering to become an astronaut.

Helen Sharman, 26, is a research technologist at Mars Confectionary in Slough, Buckinghamshire. She left Sheffield University with a BSc in Chemistry in 1984 and joined GEC as an engineer. Her present job involves researching the chemical and physical properties of chocolate, recipe development and research into new raw materials. Much of Helen's spare time is taken up with studying for a PhD in the luminescence of rare earth ions at Birkbeck College, London. She enjoys cycling, running, badminton. squash, swimming and playing football Helen lives in Surbiton, Surrey.

Timothy Mace, 33, is a Major in the Army Air Corps. During his career, he has served with NATO forces in Europe and also worked in Central America where he was involved in jungle support flying. He has a BSc in Aeronautical Engineering and, as a graduate of the Military Flying School, is an advanced instructor of helicopter pilots. His pursuits include freefall parachuting and he is a member of the British National Parachuting team. He is currently British Freefall Parachuting champion and recently came fourth in the world championships. He lives in Weyhill, Hampshire.



Clive Smith, 27, is a lecturer in aeronautical engineering and space technology at Kingston Polytechnic, Surrey. He took up this post a year ago after a career with British Aerospace, working with BAe's Space Systems Division. He is a graduate of Kingston Polytechnic with a BSc in Aeronautical Engineering. He has also won a scholarship to the International Space University in Strasbourg, France, which he attended from June to September this year. Clive plays squash, football and tennis and lives in Hampton, Middlesex.



Mir Mission Report

Aboard the Mir Space Station Soviet Cosmonauts Aleksandr Viktorenko and Aleksandr Serebrov are still awaiting the arrival of the first 20 tonne add-on module. The module was due for launch on October 16. But problems with the spacecraft guidance system have caused a delay. Meanwhile cosmonauts have been selected for the Soviet/Austrian and Soviet/Japanese missions. *Neville Kidger* has the details.

By Neville Kidger
with additional material by
Mikhail Chernyshev,
Novosti Press Agency

Settling in on Mir

Soyuz TM-8, was guided manually to the Kvant port at the rear of the complex by a floodlight illuminating the docking port, docked at 2225 GMT on September 7. The two cosmonauts crossed over into the station at 2346 GMT the same night, in the early morning Moscow Time.

The cosmonauts had taken a decision, after consultation with flight control staff, to pursue the option of manual approach and docking. They were not the first crew to have to take over from automatic control and dock manually during a Soyuz T or TM approach.

Describing the misalignment during the final automatic approach of Soyuz TM-8 to the Mir station on September 7 (Spaceflight October 1989 p.333) mission director Vladimir Solovyov, himself an experienced cosmonaut, said that the situation did not constitute an emergency. Many of the cosmonauts considered manual steering more reliable.

Cosmonauts Aleksandr Viktorenko and Aleksandr Serebrov (call sign "Vityazi") adapted quickly to their new conditions of weightlessness on the orbital complex Mir. Both cosmonauts had made previous space missions.

Their first tasks involved transferring the complex's life-support and temperature control systems over to manned operation. Science work during these early days was confined to observations of various sections of the celestial sky with the international Roentgen observatory mounted on the Kvant module.

The men also began to unload the more than two tonnes of cargo delivered to the complex by the uprated Progress-M cargo spacecraft in late August and docked with the front radial port of the Mir base block.

During mid-September the flight plan envisaged for the cosmonauts was detailed by Soviet sources and reported in the West (see ***Spaceflight,*** November 1989, p.363). The cosmonauts were to accomplish "a colossal amount of work" during their six monthly tenure on the complex, according to Lt-Gen Kerim Kerimov, the head of the State Commission overseeing manned space missions.

The launch of the first two 20 tonne add-on modules was planned for October 16 with docking planned for October 23 under the flight plan.

During September the cosmonauts' works included a changeout of the computer memory of the base block - a task which would occupy several days. The upgraded memory was to be the first such complete changeover, mission controller Viktor Blagov said.

On September 13 the propulsion system of Progress-M was used to modify the trajectory of the complex. By September 15 they had begun growing different monocrystals in the Gallar installation. The experiment was aimed at producing silicon-based semi-conductor materials in the microgravity conditions of space for use in microelectronics.

During their second week they continued the work with Gallar and the X-ray telescopes and also replaced a storage battery in the power supply system. Blagov said that the three batteries on the station were to be replaced because they were not up to full capacity. There had been reports that the previous crew, which returned to the Earth on April 27 1989, had been brought home, in part, because of a battery problem.

Medical examinations of each man and readings of the charged particle environment in and around the complex were also conducted.

On September 22 the Soviets said that the men had conducted more preventative maintenance on the complex as well as their astrophysics, medical and Earth observations experiments.

Solar Flare

By September 29 the cosmonauts had installed and checked out an additional electronic unit in the docking system in preparation for the docking of the two modules.

It later emerged that, on the night of September 30, a solar flare erupted on the surface of the Sun. According to the Soviet report, issued on October 12, flare particles are generated for 5 to 10 minutes or 24 hours at the most before irradiation settles at the background level. The September 30 flare event was so strong that the process took almost a week.

Some ten hours before the flash reached its peak Soviet scientists had produced a mathematically substantiated forecast which was turned over to the radiation safety group of the flight control centre. Mir's orbit is arranged so that the Earth's geomagnetic field reliably protects the inhabitants from peak exposure to solar and galactic radiation. The prediction was that the two men could receive more than a few hundred millibars of radiation. The maximum permissable exposure being 50 bars.

It was decided to dispense with special safety measures. In the event the men were exposed to 0.6 bars. The cosmonauts would normally receive such a dose in two weeks of flight during the normal radiation situation. The conclusion was that the addition was totally innocuous from the medical point of view considering their flight duration of six months. (The Soviets do point out, however that during a manned Mars expedi-

tion, which could last for two years or more, it is much more difficult to ensure the cosmonauts' radiation safety in open space with direct exposure to galactic rays.)

During early October the two men began a series of Earth observations using the KATE-140 topographical camera and the MKS-M and Spektr-256 spectrometers. They used a highly accurate gauge called Lyulin, to assess the radiation situation around the complex. Such readings were taken twice a day in different parts of the station, an important operation in view of the radiation situation that the flight control centre was monitoring.

Programme Alterations

On October 10 TASS reported that "considerable changes" had been made in the mission programme of the Vityazi because the launch of the first module - the additional equipment one - had been delayed for 40 days from the original date of October 16.

Vladimir Solovyov revealed that some elements of the Kurs (Course) system which guided the module to Mir had proved unreliable during ground tests.

Writing for ***Spaceflight,*** Novosti science commentator Mikhail Chernyshev says that Soviet cosmonauts and experts had proudly contended that, unlike production plants in other Soviet industries, their schedules are unfalteringly observed. But such contentions are increasingly becoming a myth.

Chernyshev describes the official announcement of the programme alterations as "an unprecedented step", saying that previously changes had been made unofficially. The public announcement showed things were going far from smoothly, as the Soviet public had hitherto presumed.

The problem lay with the Kurs system for guidance and docking of the module with Mir. Vladimir Solovyov told Chernyshev that during ground testing the system had malfunctioned. The Council of Chief Designers, having analysed the situation, and aware that the module was very expensive, decided to postpone the launch for 40 days to correct the system.

Kurs is a second generation radio technical system with adequate back-up facilities, writes Chernyshev. It had been used nine times to dock spacecraft without failure. However, the four failures during ground testing had made engineers wary. The faults apparently lay with computer chips supplied by a Voronezh factory operating under the auspices of the USSR Ministry of the Electronic Industry The factory supplies parts and components for space projects and household electrical components.

The high requirements of technology for space applications should have prompted the factory to improve its production technology. But the manufacturers apparently aimed for increased production while ignoring quality, according to Chernyshev The resulting reschedule of the space programme disrupts the operations of the organisations in charge of the Mir project and also inflicts material losses. But the losing partner cannot apply any sanctions against the supplier.

The programme rescheduling was announced by Viktor Blagov. The launch of the D module would now occur on November 28. According to a Radio Moscow report, the module will dock with Mir on December 4. On December 7, Soyuz (sic) will return, and on December 15 Progress-M2 will be launched to dock two days later.

A new computer, called Salyut, will be installed to replace the Argon computer used on Soyuz and Mir for many years. Salyut features a memory which is larger, faster and more powerful than previous versions.

The five EVAs planned at the beginning of the mission and outlined in the last ***Spaceflight*** are still to be performed with the first tests of the Soviet MMU occurring before the end of the Vityazi mission which is still planned to land on February 19, 1990.

The launch of the T module has been postponed to March 30. It has also been revealed that, following the docking of the T module, an EVA will be performed to move solar panels from the module to a location on Kvant.

Cosmonauts Viktorenko and Serebrov reacted in "a reserved manner" to the news of the rescheduling and began to observe the surface of Earth on a regular and systematic basis waiting for the module they had trained so long and hard to work with to be launched.

Future Flights

Viktórenko and Serebrov are set to return to Earth on February 19, 1990, as originally scheduled. A new crew to continue manning the Mir complex will be launched on 11 February and will dock two days later.

The replacement crew will most likely consist of cosmonauts Anatoli Solovyov and Aleksandr Balandin. There is a possibility that a third crewmember will fly on Soyuz TM-9 with these two and return with Viktorenko and Serebrov. Names which have been unofficially linked with upcoming space flights are experienced cosmonaut Vitali Sevastyanov and "Wolf Pack" Buran pilot Rimintas Stankyavichus. Another experienced cosmonaut - Georgi Grechko - said he was in training for an upcoming Mir flight earlier in 1989.

Sevastyanov was in the Flight Control centre for the docking of Soyuz TM-8. Sevastyanov is anchor man for a Soviet popular science TV programme and it has been suggested that he may fly to become the first Soviet journalist in space.

Journalist In Space Controversy

As reported in previous ***Spaceflight*** articles, the Soviet press fraternity was in uproar when the Glavkosmos agency signed a commercial agreement with the Japanese TV station Tokyo Broadcasting Station which covered the flight of a Japanese journalist on the Mir complex in 1991. The cost to TBS is reportedly $12 million.

In response to the pressure Aleksei Leonov, Deputy Head of the Cosmonaut Training Centre at Star Town, revealed that a Soviet journalist could make a flight as early as November 1990.

In early November, Radio Moscow announced a group of Soviet journalists were going through medical training in preparation for a flight in 1991.

Japanese Cosmonauts Selected

TBS initially screened over 150 applicants. In August seven candidates underwent complete medical examinations in Moscow. Of the five remaining candidates TBS eventually announced, on September 18, that two had been selected to go to Star Town to train for the actual mission.

The two candidates, a man and a woman, were presented to the press the same day. They are Toehiro Akiyama, a 47-year-old graduate of the International Peasant University and currently deputy head of TBS' International News Department and Ryoko Kikuchi a 25-year-old graduate of Tokyo's Foreign Studies University. She is TBS' only camera woman. Akiyama reportedly passed the medical tests in an "unusually sturdy" condition despite having recently given up smoking up to 80 cigarettes a day!

The first ordeal for the two was an appearance on a TBS chat show wearing what TASS called "glittering space suits" with USSR and Japanese flags and the legend "Space Reporter" across their chests. A rather less flattering account said the suits resembled cast-offs from an old science fiction series.

On October 1 Akiyama and Kikuchi arrived at Star Town to begin their training. The prime candidate will be announced about one month prior to the launch.

Austrian Cosmonauts Selected

Surrounded by rather less controversy, on October 6, the Austrians announced their two candidates for the 1991 commercial mission to Mir, called AustroMir. The two are Klemens Lothaller and Franz Fibeck. Seven candidates, including two women, were tested in Moscow.

Lothaller, a 26-year-old anaesthesiologist, was born in Vienna. Following graduation from a medical institute he served in the army. He is currently employed at the surgery department of a Vienna clinic.

Fibeck is an electrical engineer by education and is three years older than Lothaller. He too was born in Vienna and after graduation from an institute worked for the Siemens company. He currently works as assistant at the chair of Measuring Technique of the Vienna Technical University.

The men are to arrive at Star Town in January 1990. The Energiya Science and Production Amalgamation of the Ministry of General Machine-Building of the USSR is the leading contributor to the realisation of the Soviet/Austrian flight, said TASS.

Ariane Launches World's Largest Commercial Communications Satellite

On October 27, an Ariane 4 lifted the largest commercial communications satellite into orbit. The Intelsat VI (F2) was successfully placed in geostationary transfer orbit.

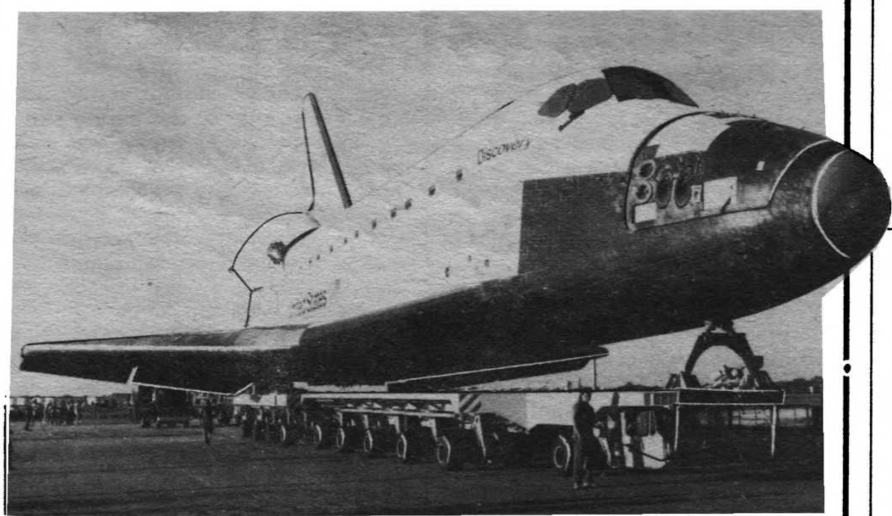
It required the most powerful version of Europe's launch vehicle to launch the Intelsat VI satellite. The Ariane 44L - equipped with four strap-on liquid boosters - was launched at 23:05 GMT on October 27.

This, the 34th Ariane launch, was originally scheduled for October 5. The launch was delayed after a new batch of electromagnetic relays was installed in the command unit of the Ariane 4 equipment bay. The original relays were found to be faulty and the countdown was halted four days before launch.

Speaking on this latest success, Charles Bigot, Director General of Arianespace, said: "Arianespace has placed into orbit the largest civil telecommunications satellite ever built. We are particularly pleased to reach this milestone with Intelsat, our first and most faithful customer, for whom we have already launched five satellites. Five other Intelsat satellite are booked to be launched by Arianespace in the years to come."

The Arianespace orderbook is now at 32 satellites to be launch worth approximately 13.7 billion FF ($2.14 billion).

The next Ariane launch is scheduled for December 13. It will carry two Japanese satellites: Superbird B and BS-2x. Another launch is scheduled for January 19, 1990. It will carry the SPOT 2 earth resources satellite and six lightweight satellites.



Discovery is moved from the OPF to the VAB by the new Orbiter Transporter. NASA

New Orbiter Transporter

A new Orbiter Transporter was used for the first time to transfer Discovery from the Orbiter Processing Facility (OPF) to the Vehicle Assembly Building (VAB) in preparation for STS-33. The transporter was originally intended for use at Vandenberg Air Force Base. It was designed to transport orbiters across mountain roads between Vandenberg AFB North Base and the VAFB shuttle launch pad, Space Launch Complex 6 (SLC-6).

The transporter was airlifted from Vandenberg AFB to the Kennedy Space Center in May. Its primary use will be to transport orbiters between the OPF and VAB. The 76 wheel vehicle rolls beneath the orbiter in the OPF and the two are joined at the orbiter/ET attach points. The transporter's bed is then elevated to lift the orbiter allowing the landing gears to be retracted. The orbiter is then ready to be transported to the VAB.

Previously, the orbiter was towed to the VAB on its own undercarriage. This created problems because the orbiter's tyres had to be fully inspected for any damage that might have occurred during the transfer. The important operation to retract the undercarriage would then take place in the VAB, after the orbiter had been attached to a crane and lifted off the ground. Any remaining tile work around the undercarriage doors could then take place.

The Orbiter Transporter allows the undercarriage to be retracted in the OPF and the tile work completed there before roll over. The tyre inspection in the VAB is no longer necessary. The new procedure is expected to save considerable time between the orbiter's arrival in the VAB and its mating with the External Tank and Solid Rocket Boosters.

SDI Satellite to be Launched on Uprated Titan 2

A satellite for the Strategic Defensive Initiative (SDI) programme will be launched by a new version of the Titan 2 launch vehicle. Eight strap-on solid rocket boosters have been added to the standard Titan 2.

The SDI Midcourse Space Experiment (MSX) spacecraft will be launched into polar orbit from Vandenberg Air Force Base. The satellite will demonstrate the technology that will be required to track and direct SDI weapons against ballistic missiles fired during a nuclear strike.

The experiment will be the first payload for the uprated Titan 2. Eight strap-on solid rocket boosters will be added to the first stage of the Titan 2. By configuring the vehicle with between two and ten strap-on boosters the vehicle can lift between 1,900 kg and 3,400 kg to polar orbit.

* A standard Titan 2 vehicle was launched on September 5 from Vandenberg carrying a classified military payload, possibly a White Cloud Navy Ocean Surveillance satellite.

Crippen Appointed Shuttle Chief

NASA Administrator Richard Truly announced two key space agency appointments at an STS-34 prelaunch press conference. Robert Crippen has been promoted to Director, National Space Transportation System (NSTS). He replaces Arnold Aldrich, who has been named as Associate Administrator for the Office of Aeronautics and Space Technology (OAST).

Former Shuttle astronaut, Bob Crippen, will have full responsibility for the operation and conduct of the Space Shuttle programme and will report directly to another former astronaut, Dr William Lenoir, acting Associate Administrator for Space Flight. Crippen made four Shuttle flights. Crippen leaves his post as Deputy Director NSTS Operations at the Kennedy Space Center. He is replaced by another astronaut, Brewster Shaw.

In his new position Aldrich will be responsible for the direction of NASA's aeronautics and space technology programmes.

The appointments are a continuation of NASA's policy to place astronauts in high management.

Military Shuttle Set For Launch

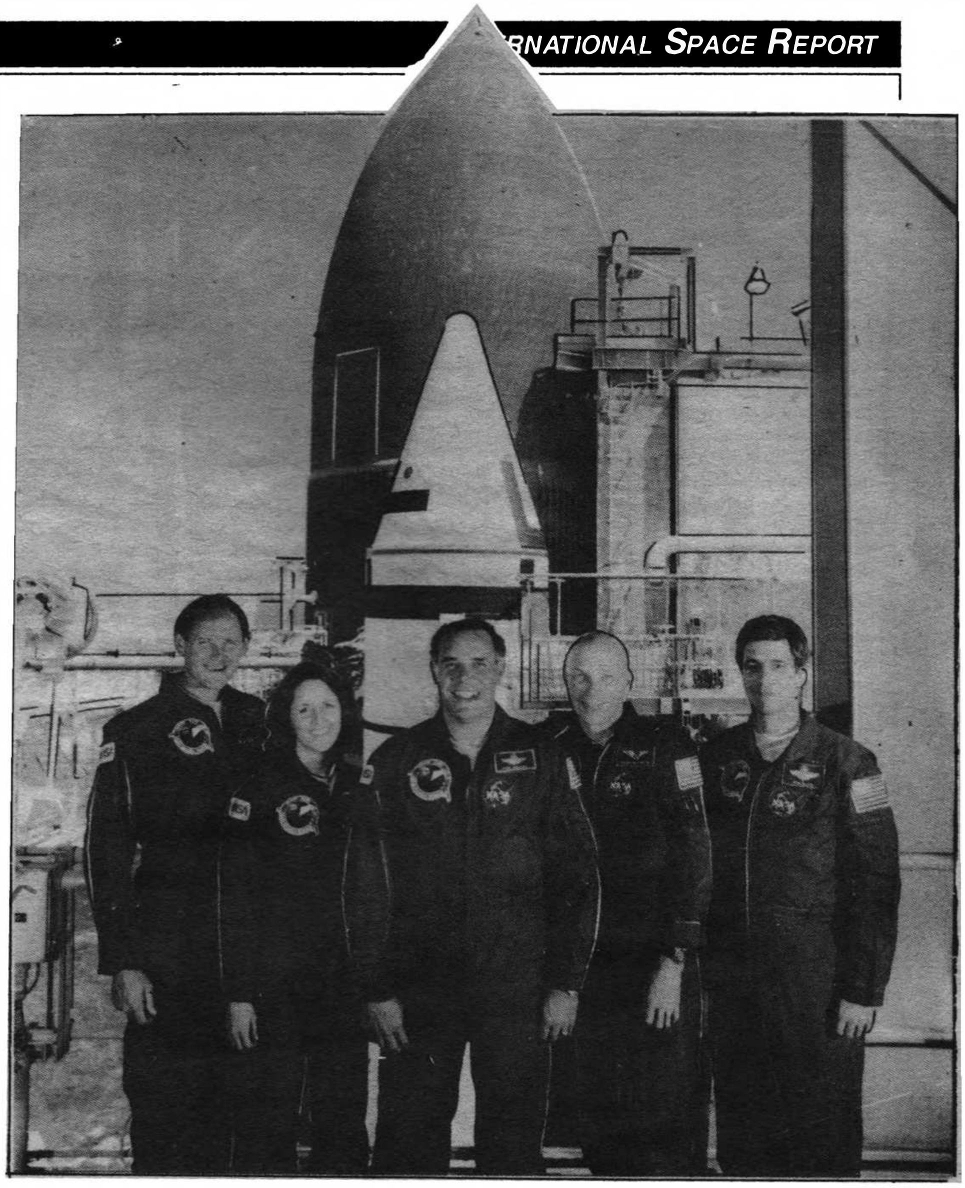
At the time of going to press the Space Shuttle Discovery was due to blast off from pad 39B at the Kennedy Space Center on a secret mission for the US Department of Defense.

Discovery was moved to the launch pad on October 27. Attempts to rollout Discovery on October 25 and 26 were abandoned because of thunderstorms in the Cape Canaveral area.

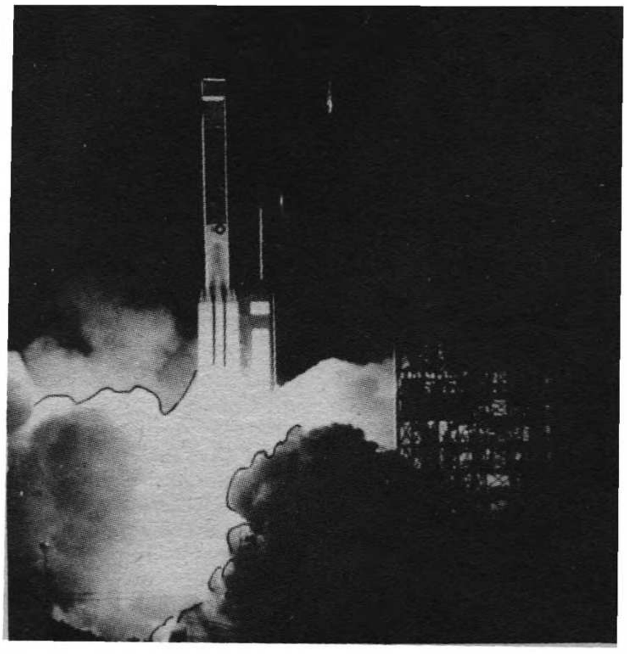
Following Discovery's arrival at Pad B a NASA payload canister was used to transport the Shuttle's secret cargo to the launch pad. The payload is believed to be a Magnum-type electronic reconnaissance satellite. As reported in last month's ***Spaceflight*** the satellite will be boosted into geostationary orbit by an Inertial Upper Stage (IUS).

According to reports the satellite, with the IUS booster attached is more than 52 feet long. Its weight in geostationary orbit will be about 6,000 lb.

STS-33 is due to blast off one day later than originally scheduled, on November 20. The launch period is four hours beginning at 18:30 EST. The mission will last four days, two hours and 13 minutes.



(Right) The STS-33 crew at the launch pad with the Shuttle in the background (left to right) Sonny Carter, Kathy Thornton, Fred Gregory, Story Musgrave and John Blaha
NASA



Delta II Launches Fourth Global Positioning Satellite

The fourth Navstar Global Positioning Satellite was launched from Complex 17 at Cape Canaveral Air Force Station on October 21. Predicted high level winds that had threatened the launch did not materialise. The Air Force announced there was a zero percent probability the launch would be aborted due to the weather. The McDonnell Douglas Delta II blasted off at 05:31 EDT into the cold Florida sky. The launch had been delayed five minutes to allow the Space Shuttle Atlantis to pass overhead. The Shuttle mission was using tracking facilities also required for the Delta launch. The satellite was placed into orbit flawlessly with all stages of the Delta vehicle performing as planned. The DoD intends to launch a total of 21 Navstar-2 satellites.

Amroc Launch Failure

The hopes of American Rocket Company for a successful first launch went up in smoke on the launch pad at Vandenberg Air Force Base in California. After an attempt one week earlier was scrubbed because of bad weather complicated by leaking thruster valves, the hybrid launch vehicle was counted down to ignition on October 5. The engine fired but the vehicle failed to lift. Chamber pressure and thrust appeared to be about one-third design values. This is tentatively attributed to failure of the liquid oxygen valve to open fully.

Once the nature of the problem was identified, the engine was shut down after a few seconds of operation with no apparent damage. Unfortunately, the guidance system computer continued to run and, following its program, injected control fluid into the nozzle of the now shutdown engine. The fluid reacted with the hot nozzle and residual engine gases resulting in a fire which rapidly spread to the composite vehicle structure. This was weakened by the fire causing the vehicle to fall over, where it continued to burn for some time. Ironically, the incident did demonstrate one of the claimed virtues of the hybrid in that there was no major explosion nor was the fire particularly intense. Such would not have been the case with a liquid or solid propellant vehicle.

Those versed in these matters will be wondering why a fire extinguishing deluge was not activated to put out the fire, in which case the vehicle could easily have been refurbished for another try. The answer is "The three-spined, unarmored stickleback". This unassuming fish, defined as an endangered species, lives in the creek at the base of the hill upon which the launch pad sits. Environmentalists feared that any water used for fire extinguishing would drain into the creek and threaten the fish. Thus, no fire deluge was allowed. While this concern for the stickleback is laudable, it is strange to consider that this pad and two others on the same ridge launched nearly 200 Atlas missiles at five times the thrust of the AMROC vehicle, using flame deflector coolant water flow rate of several thousand gallons per minute without obviously damaging our finny friends.

AMROC hopes to recover and prepare another vehicle for launch within a few months but this failure is clearly a major disappointment.

J.R. French

$360 million Contract for British Aerospace

British Aerospace and Orion Satellite Corporation (Orionsat) have signed a $360 million contract under which a British Aerospace-led international team will manufacture and provide in-orbit delivery of two Ku-band communications satellites to Orionsat. the deal marks the first time a European company has sold communications satellites to the United States.

British Aerospace will be prime contractor with responsibility for design, manufacture, launch and ancillary services. The satellites will be launched on the General Dynamics Atlas IIA launch vehicle, an improved and uprated version of the Atlas-Centaur. Other key members of the team include Matra (France), Fokker (Holland), Marqardt and Eagle Picher (US) and Telesat (Canada).

The spacecraft will be based on the Eurostar satellite bus, developed jointly by British Aerospace and Matra in partnership as Satcom International. The satellites are scheduled for delivery in 1992. Occupying Atlantic Ocean orbital positions at 47.0 and 37.5 degrees west longitude, they will provide communications services to the United States, Europe and Africa.

Hubble Arrives at Kennedy Space Center

The Hubble Space Telescope has arrived at the Kennedy Space Center and is undergoing final tests and checkouts before its launch on March 26, 1990.

On October 4, a specially modified US Air Force C-5 transport whisked the Hubble Space Telescope from its Californian clean room to the Vertical Processing Facility at KSC. The move was made in complete secrecy at the insistence of the USAF. The space-based observatory was transported in the same container as the United States' latest photo-reconnaissance satellites. Air Force officials have kept the container under wraps so the shape of its spy satellite cannot be deduced from the transport canister. This policy has been ridiculed in the US press. It does not take an expert to realise the Hubble Space Telescope and the top secret reconnaissance satellite must be the same shape if they can travel in the same container.

Although the Challenger accident and Shuttle payload rescheduling delayed the telescope's launch, programme officials have used this time well. They made several improvements including more efficient ground and flight software, improvements to ease astronauts' on-orbit work, a longer life power system with new solar arrays - supplied by British Aerospace - and an increased lifetime on many components.

NEWS IN BRIEF

Secret Shuttle Short Circuit

The STS-28 crew pose for the traditional in-flight photograph. (From top clockwise) James Adamson, David Leestma, Mark Brown, Richard Richards and Brewster Shaw *NASA*

NASA has revealed there was a potentially dangerous incident during the STS-28 DoD mission in August. The use of the teleprinter was discontinued after a short circuit in the power supply cable. The crew reported seeing sparks and some smoke was recorded by the cabin smoke detectors, although it was not enough to sound alarms aboard Columbia. An investigation revealed the cable had become crimped causing a short circuit lasting about one and a half seconds. A second, more serious problem was reported in Aviation Week & Space Technology. The magazine says the spy satellite deployed from Columbia malfunctioned soon after deployment and is now tumbling out of control. Meanwhile NASA has released selected onboard photographs from STS-28.

Pegasus Launch Delayed

The launch of the first Pegasus Booster has been delayed until December. The launch was postponed because of problems with the attachment between the booster and its carrier aircraft.

$650 Million Engine Deal

Rockwell International's Rocketdyne Division has signed a $650 million contract with General Dynamics Space Systems Division. This is one of the largest contracts ever authorised by General Dynamics. Rockwell will provide General Dynamics with 61 sets of Atlas booster and sustainer engines to support the Atlas I and Atlas II programmes, to launch payloads into space for commercial, US Air Force and other government projects.

SPACE AT JPL

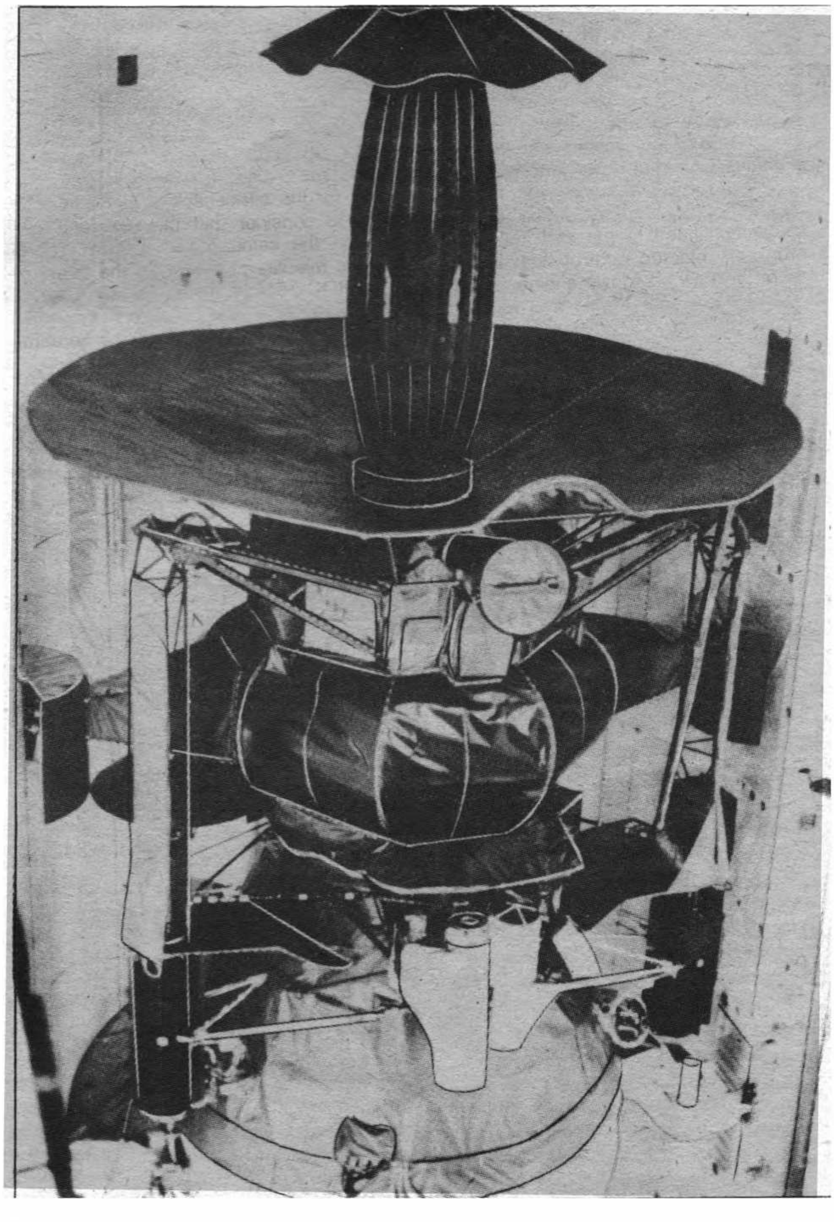
The latest news from Dr. William McLaughlin at the Jet Propulsion Laboratory in California.

Galileo Launched

THE long-awaited launch of the Galileo spacecraft took place on Wednesday, October 18, 1989. At 12:53:40 PM, Eastern Daylight Time, the space shuttle Atlantis lifted off from the Kennedy Space Center (KSC). It carried the Galileo Orbiter and Probe and the means to transfer them, after deployment from the shuttle, from low Earth orbit to interplanetary space: the Inertial Upper Stage (IUS) rocket. Twelve years after its initiation as an approved flight project and seven years after its first planned launch date, the mission operations phase of Galileo has begun as the spacecraft starts on its six-year, 4,000 million km flight to Jupiter. The spacecraft is now (a few weeks after launch) performing in a nearly flawless manner. The operations team is characterizing the flight properties of the vehicle and learning to fly it with confidence.

People on Project Galileo pride themselves on being survivors. Originally scheduled for a launch in 1982, a series of launch-vehicle problems slipped the plan by seven years. (The spacecraft came very close to being launched in 1986; set for a May liftoff, the Challenger exploded in January and necessitated a reset.) In addition, the existence of the project was placed in jeopardy in the early 1980s by threatened funding cuts, and, more recently, a legal injunction was (unsuccessfully) sought before launch in order to prevent carrying aloft the plutonium-based Radioisotope Thermoelectric Generators (RTGs) which supply the spacecraft with its electrical power. So, the flight team took in stride the effects on the project of hurricane Hugo (which occurred while the Atlantis was on the launch pad), the San Francisco earthquake (a control centre for the IUS is in northern California), a launch slip from October 12 due to a shuttle problem, and a launch slip on October 17 arising from unsatisfactory weather.

During the long cruise to Jupiter, Galileo will take advantage of several scientific opportunities with a frequency of about one per year. In February 1990, the spacecraft will fly within about 15,000 km of Venus (see the March 1989 edition of this column). Later that year, in December, Galileo will pass through the Earth/Moon system with an opportunity for good science at both bodies. Asteroid Gaspra, with a diameter of approximately 15 km, will be observed at distances as close as 1,000 km in October 1991, and the spacecraft will return to the Earth/Moon system for the second and last time in December 1992 for its third gravity assist (Venus-Earth-Earth). Finally, a 1000 km flyby of (30 km diameter) asteroid Ida is an option for August 1993.

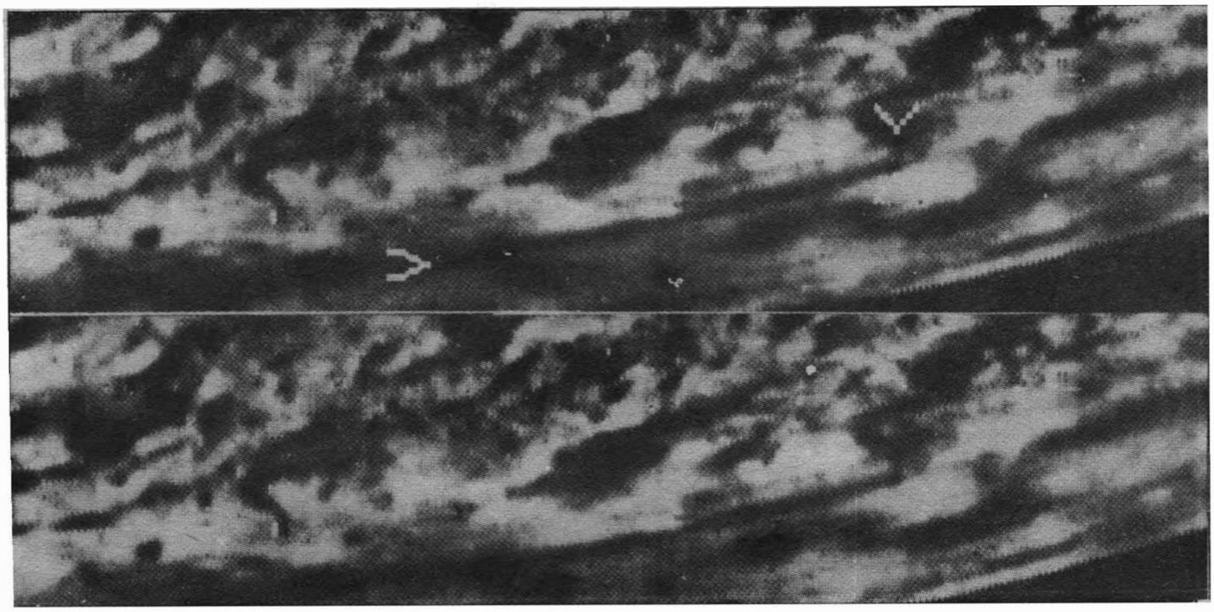


Galileo pictured in Atlantis' payload bay at launch Pad 39-B on October 9. *NASA*

Preparations for encounter with Jupiter include the release of the Jovian atmospheric Probe 150 days before the December 7, 1995 arrival of the Orbiter at the planet. For 22 months (the prime mission phase), Galileo will investigate the Galilean satellites (Io, Europa, Gamymede, and Callisto), the magnetosphere, the planet, and its rings.

Our present conception of the Jovian system is based upon results from the four rather distant flybys by the Voyagers and Pioneers. Prepare to be surprised when Galileo arrives at Jupiter and starts returning data.

An Active Geyser on Triton

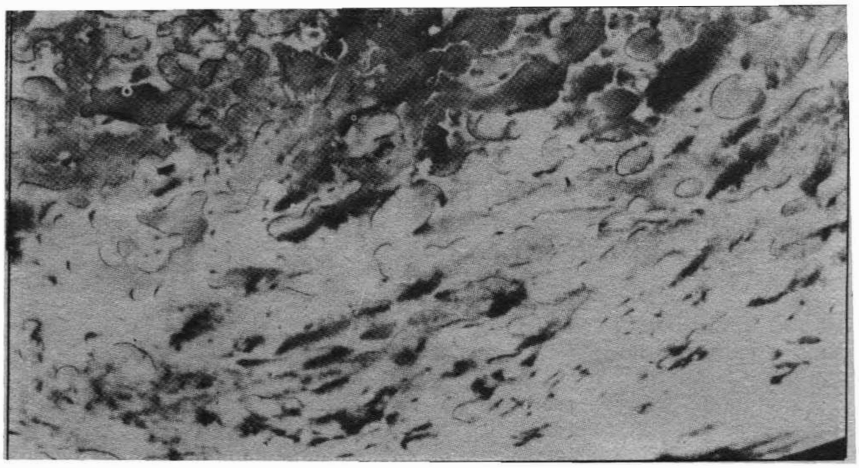


An active geyser on Triton was caught in the act by Voyager 2 on August 24, 1989. NASA/JPL

ON October 2, it was announced that an active geyser had been discovered on Neptune's largest satellite, Triton, in an image taken earlier during Voyager 2's flyby of that system. The image, taken on August 24 from a distance of 99,920 km, shows the narrow stem of a dark plume rising almost 8 km in Triton's thin atmosphere and forming a cloud seen to drift 150 km westward, driven by winds.

Although the hypothesis of geysers had been invoked at the time of near encounter - to explain about 50 black streaks seen in the south polar region - confirmation was truly an astounding discovery. Triton is the coldest object yet visited by Voyager, with temperatures of approximately 40°K in the lower atmosphere. Hence, the energy to power the geysers is not easy to come by; sunlight is a likely candidate, but the Sun appears to shine at Triton with only 1/900 of its strength at Earth.

Pressurized nitrogen may form the bulk of the material exiting the vent hole, with an admixture of organic molecules contributing the dark colour to the plume. Although Triton's atmosphere, consisting principally of nitrogen, has only 1/100,000 the "sea level" pressure of Earth's, some structure was earlier observed in the form of a haze layer of aerosols suspended a few km above the surface of the satellite.



Dark streaks on the southern polar cap of Neptune's large satellite are evidence of geyser activity NASA/JPL

It is currently summer in the southern hemisphere of Triton with the Sun approaching its most southerly latitude.

The immediate resource gained from a Voyager planetary encounter is represented by the scientific data which have been returned to Earth. In time, these results are incorporated into an evolving picture of the solar system. The quickest way to update a mental image is just to look at the images and first interpretations of data "to see what it is like." This is an unforgettable experience on the day of encounter (see the October edition of this column), and it has given me corresponding pleasure to be able on occasion to present early results at meetings.

One such occasion was at the British Interplanetary Society meeting room in London on October 4. At the end of the presentation, as I was preening myself on having completed another act of enlightenment, a question was asked; had I seen the newly released image of an active geyser on Triton? No, I had not. Thanks to an air express delivery, I was able to obtain a slide of that delicate effusion and, at an October 13 science seminar I gave at ESA's ESTEC facility (in Noordwijk, The Netherlands), see with the audience this wonder on the screen of the auditorium.

Interstellar Flight

FLIGHTS beyond the confines of the solar system have been advancing in psychological credibility as our exploration of the solar system becomes more comprehensive. Having flown past Neptune in August 1989, Voyager 2 joins Voyager 1, Pioneer 10, and Pioneer 11 in the quest for one measure of the boundary of the solar system: the heliopause, where the influence of the solar wind ceases. The achievement of interplanetary flight waited upon the development of adequate launch capabilities, a problem solved in large part by the staging of chemical rockets. Similarly, most plans for interstellar flight centre upon the need to develop adequate propulsion systems – which would yield "reasonable" times of traverse for the vast gulfs of interstellar space. The solution to the propulsion problem need not lie with rockets, chemical or otherwise.

A recently published compendium, *The Starflight Handbook* by Eugene Mallove and Gregory Matloff, succinctly reviews the major aspects of the subject and complements the above-mentioned psychological credibility with a sense of technological possibility. My personal transactions with the stellar universe have, on the whole, been conducted by astronomical means or through the radio-based search for extraterrestrial intelligence (SETI). Hence, upon reading Mallove and Matloff, I was not surprised to receive unbidden impressions concerning this third channel to the stars. But the fact that the two major associations which came to my mind relate to education and ancient Greece may merit some explanation.

Education in the widest sense is not restricted to the transmission of knowledge from one segment of society to another; it may also include generation of new knowledge. A few subjects — the measurement of time, the understanding of the Moon's motion, the theory of games have yielded instruction beyond their natural domains. The case for interstellar flight as a topic which will provide an important source of instruction rests upon: (1) the high probability of its continued pursuit and eventual accomplishment, e.g., see "Where are They?" in the May 1986 "Space at JPL", wherein the supposed inevitability of interstellar flight serves as a foil to SETI Theories, and (2) the fundamental investigations into physics, biology, engineering, and sociology which it requires.

Mallove and Matloff devote seven of their sixteen chapters to a discussion of methods of propulsion for flights beyond the solar system by rockets or other means.

The litany of techniques involving the use of rockets - devices which expel mass at high velocities and rely upon the justice of the law of conservation of linear momentum - is in itself rather extensive

The increment of velocity imparted to a rocket is proportional to both the velocity of its exhaust and the natural logarithm of its mass ratio: the ratio of the initial mass of the rocket divided by the mass remaining after expulsion of propellant. These proportionalities, encoded in the so-called rocket equation, which is derived by straightforward calculus from the differential statement of the conservation of momentum, narrow the search for better rockets to two basic areas: more "energetic" propellants and/or larger relative accumulations of same. A commonly used measure of exhaust velocity is the "specific impulse" (usually seen as "I_{sp}" in the literature). It can be numerically obtained by dividing the rocket's exhaust velocity by the acceleration of gravity, "g" (so the units of I_{sp} are seconds). Or, if velocities are measured in m/s, dividing this quantity by 10 very nearly yields the I_{sp}.

Chemical rockets, solid or liquid, typically achieve specific impulses of hundreds of seconds and, according to Mallove and Matloff, could go as high as two or three thousand with some rather exotic fuels. In the search for higher velocities for interstellar spacecraft, electric propulsion engines appear more promising than chemical means. These devices use an electric power generator to ionize atoms and accelerate them to high speed using electric fields. Specific impulses of thousands of seconds have been obtained, and hundreds of thousands of seconds might eventually be possible. However, the requirements on electrical power generation are severe for ion engines.

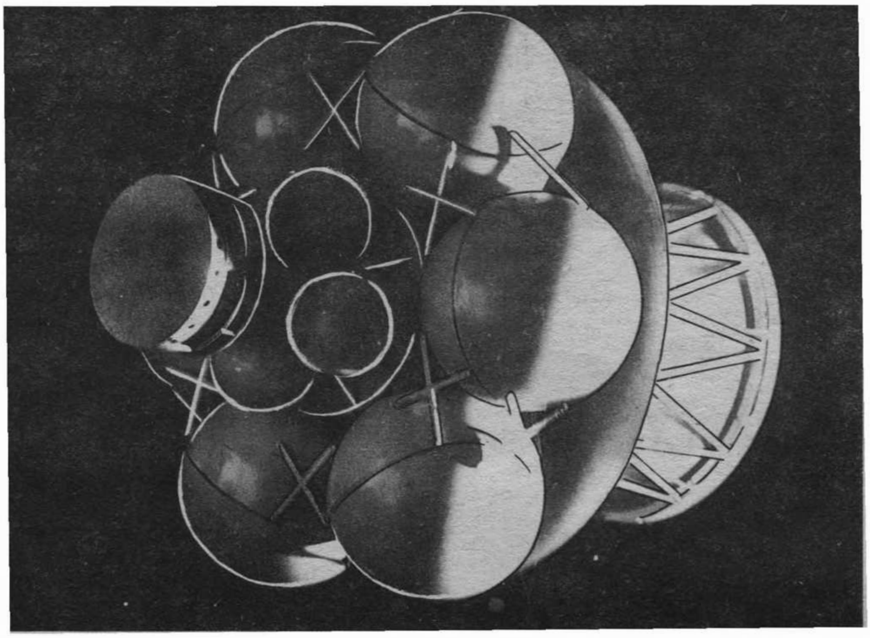
Nuclear fission and nuclear fusion have also been proposed as energy sources for rockets as well as the more exotic concept of using antimatter. In the 1950s, Eugen Sänger proposed the mutual annihilation of matter and antimatter to produce gamma rays. These energetic photons, travelling at the speed of light, would have the highest possible specific impulse; approximately 3×10^7 seconds. Further consideration has reduced the expected capability of an antimatter rocket, but the big economic difficulty is obtaining sufficient quantities of antimatter; the current cost is estimated at one hundred thousand million dollars per milligram!

Nuclear pulse propulsion designs have taken a startlingly primitive idea – exploding a series of nuclear devices behind a spacecraft in order to push it forward — and developed it to a relatively advanced state (on paper). Project Orion in the U.S. in the 1960s and the Daedalus project of the British Interplanetary Society in the 1970s yielded system designs of considerable sophistication. The 10^6 second I_{sp} engines of the 450 ton (payload) Daedalus spacecraft would propel the vehicle to Barnard's star, 5.9 light years away, in about 50 years, reaching speeds up to 12% of light.

Starship design requirements stimulate large reservoirs of creative energy. In addition to themes within the rocket family, propulsion by sails has been envisaged: sails which would catch a wind of photons from the Sun or a beam from a bank of orbiting lasers. If solar photons were used to drive the sail ship, a close passage by the Sun would be required in order to yield sufficient initial velocity to carry the spacecraft on its way through regions where the Sun would constitute only a dim presence.

In 1960, Robert Bussard conceived a spacecraft, the interstellar ramjet, functionally patterned after stars themselves. A star is created when part of an interstellar molecular cloud gravitationally collapses and, after sufficient heating of the core through compression, begins to convert hydrogen into helium by thermonuclear reactions. Instead of accumulations of fuel by gravitational collapse, Bussard's ramjet would scoop ions in the front end of the vehicle using an extended electromagnetic field. Then, energy from a star-like fusion reaction would provide thrust by sending the products of reaction toward the rear.

The expected feasibility of interstellar ramjets and their variants has periodically waxed and waned since Bussard's initial proposal, but the flow of new engineering ideas for propulsion continues. For example, in 1963 Freeman Dyson foresaw the utility of certain double star systems as "gravitational machines" capable of accelerating a spacecraft to a substantial fraction of the speed of light if a properly designed gravity-assist trajectory were employed. Mallove, in 1976, even sketched an idea for sending a starship on its way using a giant cosmic "scissors". Physicists have boldly



A model of the British Interplanetary Society's Daedalus concept. *Mat Irvine*

speculated that it might be possible to travel at speeds greater than that of light by utilizing "wormholes" in space-time. Only slightly less exotic is the proposal by E.D. Froning to tap the quantum fluctuations of energy which inhere in the vacuum.

The preceding sketch of approaches to interstellar flight is submitted as a demonstration of the fertility of the idea – its "educational" aspect. For interstellar starflight *per se,* the availability of tested engineering systems is difficult to forecast. Perhaps Brice Cassenti's estimate of 10-light-year ranging capability within 200 years from now is not unreasonable (see the March 1982 ***JBIS,*** pp. 116-124).

Short of superluminal schemes such as "wormhole" travel, interstellar flight is likely to be a time consuming activity whenever it becomes feasible. If interstellar flight is viewed as a mode of transportation, then, with regard to the elapsed time of passage, "long is bad". However, if it is viewed as an end in itself, the quality of the time assumes primary importance. Trams and utopias are judged by differing criteria. But regardless of the reasons for undertaking a long passage, a viable onboard social structure is essential.

The idea of interstellar space arks or generation ships or of city states orbiting within the solar system is certainly not new. My intent is restricted to looking at the relevance, in the context of the sociology of interstellar arks, of one of the two most celebrated treatises of Greek political thought, Aristotle's *Politics.* (The other work is, of course, Plato's *Republic.*)

There are two hurdles to be passed before we can consider the judgments in the *Politics* with any degree of comfort. First, Aristotle, and the classical world on the whole, offends our modern sensibilities with his restrictions on who is to be accepted as a citizen: mainly Greek males of property. But Aristotle – like the modern world struggling with diverse views on animal rights and human conception -- was a prisoner of his intellectual environment. W. R. Connor's article "After Smashing the Wedgwood" (*The American Scholar*, Autumn 1989, pp. 533-541) makes a good case for historical tolerance.

Second hurdle: can an ancient Greek city-state, largely agricultural, contain lessons of value for, say, a colony based on a laser-driven starship? Yes; in fact I believe that herein lies the strength of consulting Aristotle. Stripped, perforce, of technological distractions, the *Politics* gets down to fundamental human values and how they can be promoted. Aristotle emphasized the continuity of his treatise *Ethics* with *Politics.* Computer simulations, economic analyses, and the like have their place, but in the absence of an underlying system of axioms of human values, they are sterile. An examination of human social issues with regard to extended starflight is relevant to our reasons for undertaking such a project and is essential to insure the survival of the community: "why and how". (Also recommended reading in this area is the collection of essays, *Interstellar Migration and the Human Experience,* edited by B.R. Finney and E.M. Jones: U. of California Press, 1985.)

A case can be made that philosophy's task is to construct promising systems of fundamental axioms and then interpret them in terms of everyday structures; city states of classical Greece or starships in 2200 A.D. An analogous approach of interpreting logical systems in mathematical structures has achieved great success in modern mathematics (under the label "model theory"). Incidentally, a given logical language may have several different interpretations, all true, a fact which may lie behind the familiar complaint that philosophy never advances.

What then might we extract of value from Aristotle's *Politics?* Read the book (the Penguin edition, with good notes, by T.A. Sinclair and T.J. Saunders is recommended). But a brief summary is appropriate.

To Aristotle, each thing, human or otherwise, is designed for a purpose. The greatest good for a human is happiness; achieving this is a human's end or purpose. This fundamental philosophical supposition contrasts with those who claim that the purpose of life is to do one's duty or to pursue pleasure. Personal happiness is obtained by the pursuit of virtue, largely reached by seeking the Aristotelian mean between extremes of behaviour or attitude. Thus, courage is a mean between foolhardiness and cowardice.

The state is an association which exists to promote the happiness of its members. In the words of Aristotle, "... those constitutions which aim to the common good are right... Those which aim only at the good of the rulers are wrong." Aristotle, the pragmatist with principles, discusses a variety of constitutions and how they can be tuned and maintained to promote the happiness of individuals under their governance.

The primary cause of instability in a state is factionalism, and it arises "whenever either side does not share in the constitution according to their fundamental assumption." Aristotle's prescription for the health of the state resembles that for the individual; achieve a balance among parts of the state. To this end, a large middle class is of importance.

Sound familiar? Of course, much of our political heritage comes from the Greek experience. The aptness of the Aristotelian counsels of virtue and balance reminds us that even among the complexities of the age of space, good results still depend upon good foundations. Numerous reasons have been advanced for undertaking human spaceflight: challenge, destiny, prestige, technology, etc. How about "happiness"?

Spaceflight
The International Magazine of Space and Astronautics

VOLUME 30
1989

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Editor: G.V. Groves, Ph.D, F.B.I.S.

Published by The British Interplanetary Society
27/29 South Lambeth Road, London SW8 1SZ

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SATELLITE DIGEST-224

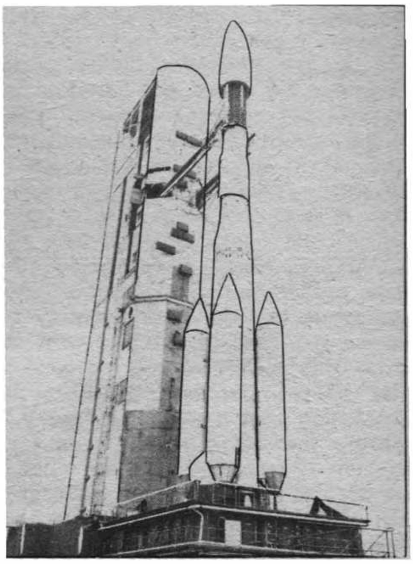
Satellite Digest is produced in two sections. Orbital Data is in the form of a table which lists each satellite's name, international designation, launch time and date, launch site, launch vehicle, perigee, apogee, period and inclination. Launch times are approximate, except when marked with an asterisk, when the time given is that issued by the launching agency. All times are GMT. Soviet launch vehicles have been named by the Sheldon system of classification. Orbital data has been provided by the Royal Aerospace Establishment. The first section, Satellite Data, contains notes on each satellite's mission.

SATELLITE DATA

COSMOS 2022 & 2023 (1989-39A & 39B): A pair of GLONASS navigation satellites. Launched with Cosmos 2024. The Proton third stage of Cosmos 2022, 2023 & 2024, designated 1989-39D, reentered scattering debris along the US-Canadian border approximately ten hours after launch.
COSMOS 2024 (1989-39C): Carries retroreflectors for laser tracking. Possibly a geodetic satellite known as Etalon. Launched with Cosmos 2022 & 2023.
COSMOS 2025 (1989-40A): Photo reconnaissance satellite based on the Vostok capsule. Recovered June 15.
SUPERBIRD A (1989-41A): Domestic communications satellite for Space Communications Corporation, Japan.
DFS-1 (1989-41B): (Also known as Kopernikus-1.) Multi-purpose satellite for Deutsche Bundespost of West Germany.
COSMOS 2026 (1989-42A): Navigation satellite.
MOLNIYA 3-35 (1989-43A): Domestic communications satellite in highly eliptical orbit.
NAVSTAR 2-02 (1989-44A): Second Block-2 navigation satellite. Part of the Global Positioning System network. Also known as USA 38.
COSMOS 2027 (1989-45A): A minor military satellite, exact purpose unkown.
DSP (1989-46A): An early warning satellite launched on the first Titan 4. The satellite was boosted into geostationary orbit by an IUS upper stage (See ***Spaceflight,*** August 1989, p.256 for further details.)
COSMOS 2028 (1989-47A): A photo reconnaissance satellite. Recovered on July 6.
RADUGA 1 (1989-48A): Communications satellite placed in geostationary orbit. Part of the Orbita-2 system.
RESURS-F 2 (1989-49A): A manoeuvrable Earth photography satellite based on the Vostok design. Recovered on July 11.
NADEZHDA (1989-50A): A navigation satellite. Also part of the international COSPAS-SARSAT rescue system. Nadezhda means Hope.
COSMOS 2029 (1989-51A): Photo reconnaissance satellite based on the Vostok capsule. Recovered July 19.
GORIZONT 18 (1989-52A): Communications satellite. Part of the Orbita-2 network.
OLYMPUS F1 (1989-53A): Experimental communications satellite developed by the European Space Agency and built by British Aerospace. Stationed at 19 degrees west. (See **Spaceflight,** November 1989, p.386 for further details.)

UPDATES

PROGRESS 39 (1988-114A): Undocked from Mir and was deorbited on February 7.
BHASKARA-1 (1979-51A): Indian remote sensing satellite decayed on February 17.
COSMOS 1958 (1988-60A): A Soviet ELINT satellite decayed on March 21.



Ariane V31 stands poised to launch the DFS-1 and Superbird A satellites *Arianespace*

COSMOS 1310 (1981-95A): Decayed on April 3 1989, after 2,749 days in orbit.
SAGE (1979-13A): Also known as AEM-2, SAGE (standing for Stratospheric Aerosol and Gas Experiment) decayed on April 11. The satellite used an onboard photometer to provide data on the ozone and aerosol content of the atmosphere.

ORBITAL DATA

Name & International Designation	Launch Time and Date	Launch Site	Launch Vehicle	Perigee	Apogee	Period	Inclin.
COSMOS 2022, 1989-39A	0824, 31 May	Baikonur, USSR	SL-12	19,122	19,137	675.73	64.81
COSMOS 2023, 1989-39B				19,095	19,165	675.74	64.83
COSMOS 2024, 1989-39C				19,099	19,144	675.41	64.83
COSMOS 2025, 1989-40A	1257, 1 June	Plesetsk, USSR	SL-4	180	356	89.86	62.81
SUPERBIRD A, 1989-41A	2237, 5 June	Kourou, French Guiana	Ariane 44L (V31)	35,769	35,804	1,435.99	0.07
DFS 1, 1989-41B				35,708	35,865	1,435.97	0.05
COSMOS 2026, 1989-42A	0515, 7 June	Plesetsk, USSR	SL-8	953	1,010	104.78	82.94
MOLNIYA 3-35, 1989-43A	1700, 8 June	Plesetsk, USSR	SL-6	593	39,763	717.80	62.83
NAVSTAR 2-02 1989-44A	2219*, 10 June	CCAFS, USA	Delta II	19,970	20,210	714.21	54.63
COSMOS 2027, 1989-45A	1245, 14 June	Plesetsk, USSR	SL-8	482	513	94.58	65.84
DSP (USA 39), 1989-46A	1318, 14 June	CCAFS, USA	Titan 4	GEOSTATIONARY			
COSMOS 2028, 1989-47A	0920, 16 June	Baikonur, USSR	SL-4	208	288	89.49	69.98
RADUGA 1, 1989-48A	2330, 21 June	Baikonur, USSR	SL-12	35,768	35,814	1,436.21	1.45
RESURS-F 2, 1989-49A	0809, 27 June	Plesetsk, USSR	SL-4	260	274	89.91	82.56
COSMOS 2029, 1989-50A	0809, 5 July	Plesetsk, USSR	SL-4	180	242	88.78	82.34
NADEZHDA, 1989-51A	1536, 4 July	Plestesk, USSR	SL-8	960	1014	104.90	82.96
GORIZONT 18, 1989-52A	2248, 5 July	Baikonur, USSR	SL-12	35,774	35,796	1,435.89	1.47
OLYMPUS F1, 1989-53A	0014, 12 July	Kourou, French Guiana	Ariane 3	35,516	36,102	1,437.61	0.32

CORRESPONDENCE

Soviet Moon Rocket's Sad Fate

Sir, I would like to add some interesting details to the October ***Spaceflight's*** summary of the August 18 Izvestiya article on the Soviet Union's N-1 moon rocket (p.333).

As you point out, there was a dispute between Sergei Koroiyov and Vaientin Glushko about the use of cryogenic or hypergoiic propellants. While Korolyov was wise enough to foresee a revolution in cryogenic technology, Glushko repeatedly spoke out against the use of the liquid oxygen/liquid hydrogen combination during the 1960s, reasoning that the low density of these propellants would require enormous fuel tanks and hence unacceptably increase the mass of the rocket. Undoubtedly impressed by the success of the Saturn V's cryogenic engines, Glushko gradually changed his mind on the matter and eventually ordered the development of the Energiya system (using cryogenic engines in its central stage) when he took over command of the Koroiyov design office in May 1974.

Although Koroiyov recognised the future potential of liquid oxygen and hydrogen, it is quite clear from the Izvestiya article that he never seriously contemplated their use on the N-1 itself (the debate over cryogenic or hypergolic propellants mainly revolved around future heavy-lift rockets). Pressed for time, the Korolyov office came to the conclusion that it would be much simpler to equip the rocket's first stage with a huge cluster of medium-thrust engines. Glushko, on the other hand, favoured a small cluster of high-thrust engines, claiming that the synchronisation of many small engines would be hard to accomplish. The propellants for these two concepts are not mentioned by Izvestiya but it is reasonable to assume that Glushko's proposal envisaged high-pressure LOX/UDMH or nitric acid/UDMH engines employing a preburner cycle (uprated versions of his RD-253 Proton engine), while Korolyov's design called for relatively modest LOX/kerosene engines (logical outgrowths of his RD-107 Semyorka engine), even though he was well aware the LOX/kerosene combination would no longer satisfy the needs of more advanced follow-on heavy-lift rockets.

Unable to reach a compromise with Glushko, Korolyov turned to another design office for the manufacture of the N-1's first stage rocket engines, namely that of N.D. Kuznetsov centred in the town of Kuibyshev. Renowned for its development of jet engines for the Tupolev aircraft, the Kuznetsov office was a newcomer to the field of rocket technology and faced the immense task of turning Korolyov's idea of a huge synchronised engine cluster into reality. The office's inexperience combined with Korolyov's death in January 1966 and the decision not to conduct any static test firings of the first stage as a time-saving and economy measure probably sealed the fate of the N-1 because, eventually, it was always a first stage failure that caused the four launch accidents (the third of which incidently occurred on July 27, 1971 according to Izvestiya, not July 21 as you state). Nothing specific is revealed about the N-1's two upper stages, except that some of the N-1's stages are still being successfully used today, which would add weight to an earlier Western suggestion that the rocket's second and third stages were actually identical to those of the Proton rocket (both built by the Chelomei offices) [1]. Given the growing success rate of the Proton by the early 1970s, the N-1 undoubtedly would have been successful if the engineers had been able to master the recalcitrant first stage.

After the fourth launch attempt in November 1972, when the first stage had failed only seconds short of burnout, the consensus among the N-1 team was that a successful launch was just around the corner. Two more vehicles were assembled at Baikonur, one slated to fly in August 1974, the other at the end of that year. If those two had ended in success, the rocket would have been declared operational, which even pessimists said at the time would be achievable by 1976.

Not surprisingly, Glushko's decision in May 1974 to cancel the project met with stiff opposition and some staunch N-1 supporters were not willing to give up even then. In 1976 N.D. Kuznetsov, eager to restore the tarnished reputation of his design office, conducted static test firings of an N-1 engine which worked flawlessly for a total of 14,000 seconds (only 114 to 140 seconds were required for first stage operation). At another point some engineers even requested permission to test two rockets over the ocean, but all to no avail.

A most strange relic now bears testimony to the N-1 days at Baikonur: an oddly shaped roof covering a bandstand in a park at the space centre, not designed as such, but a converted remnant of an unused N-1 fuel tank. A sad fate for what was to have been part of a moon rocket.

BART HENDRICKX
Belgium

Reference

1. J. Parfitt and A. Bond, "The Soviet Manned Lunar Landing Programme", *JBIS* May 1987, p. 231-234.

Commanders of the Soviet Cosmonaut Team

Sir, You may be interested in the following information about the Cosmonaut Team:

On May 25, 1961 a new post of Commander of the Soviet Cosmonaut Team was introduced. The following cosmonauts have held the position:

1. Yu.A. Gagarin was the first Commander until his death on March 27 1968.
2. A.G. Nikolayev (April 1968 - June 1968).
3. V.F. Bykovsky (July 11, 1968 - March 21 1969).
4. From April 1969 - July 1975 the main cosmonaut team was broken into smaller detachments in accordance with the flight programme.
5. In July 1975 the cosmonaut team was re-united under the leadership of A.A. Leonov, who held the post until January 1982.
6. V.V. Gorbatko (January 25, 1982 - August 1982).
7. B.V. Volynov (since August 1982).

SERGEY A. VOEVODIN
Kostroma, USSR

The Cosmonaut Team

Sir, In my previous letter to ***Spaceflight*** (Correspondence, November 1989, p.391) I assumed Moskalenko was still active. I now know this to be incorrect. He has left the cosmonaut team and has been reassigned to the Air Force.

I can provide further information about the cosmonaut team:

- Anatoliy Solovyov, Aleksandr Serebrov and Nikolay Moskalenko were the 2nd back-up crew for Soyuz T-14.

- Two military pilots joined the cosmonaut team in 1978. They were: Aleksandr Viktorenko and Nikolay Grekov. Viktorenko is currently in orbit. Grekov had step down as a cosmonaut after suffering from jaundice. He now works at the Flight Control Centre.
- It seems Viktor Afanasyev and Vitaliy Sevastyanov were the 2nd back-ups for Soyuz TM-8. They might be the back-ups for Soyuz TM-9 and then the prime crew for Soyuz TM-10. Alternatively, they might be a short visit crew. Soviet television showed Afanasyev, Sevastyanov and Rimantas Stankyavichus during splashdown training.

VADIM Y. MOLCHANOV
Tula, USSR

Unmanned to Mars and a Cleaner Earth

Sir, On July 20, 1987, President Bush publicly endorsed manned missions to Mars and the Moon. Actual costs are not known at this time, but it will certainly be expensive.

Compared with what could be achieved with a $30 billion dollar unmanned program that lands several rovers on Mars able to roam the surface for a couple years, an automated sample return, a permanent Mars orbital observatory to watch for long-term patters and trends, and probes of the two Martian moons, it seems unclear what added value is gained from the extra $120 billion it would take to ship humans to do the same things and perhaps less.

Manned space advocates claim that the public experiences some sort of emotional relationship to astronauts, that people are excited by sharing exploits and not by the return of data. So perhaps one of the rovers should be dedicated to public access.

It is important that access be open to those who pass a short training course and pay the access fee regardless of the value of their "mission" - perhaps just panning a video camera or picking up a rock or just walking over that tantalizing little hill off to the right there.

It is important to keep in mind that, while interesting, the other planets are desolate rocks. Humans can briefly survive there only with great effort, expense and technology. The urge to ship humans as soon as possible is misguided. Robots will be adequate for many years.

Therefore mount a thorough mission to Mars with public access Use the $120 billion saved by not shipping unnecessary humans to plant unnecessary flags, for the development of cars that do not pollute, solar energy or environmental clean-up and the protection of the diversity of life on Earth.

An incredibly valuable piece of data has already been returned by the space program: the Earth is unique in this Solar System. We do not have a second chance, there is nowhere else to go. If we are not acting with vigour on this most valuable of all data from the space program, should we spend to accumulate more data to ignore?

JON GIORGINI
Texas, USA

The Martian Calendar

Sir, Most would agree that it is desirable to be able to divide the Martian year into quarters; nearly all writers on the subject have done this. Here we reach a point of departure, for while 167 is a prime number, 168 may be broken down into 24 x 7, 12 x 4, 8 x 21, 6 x 28, 4 x 42 and 3 x 56. The last number in each of these pairs is divisible by seven, so it is natural for us to adopt the seven-sol week on my Martian calender (***Spaceflight,*** July 1988, p.278), the mathematics happened to fall out that way.

This existing convention appears to work well on Mars - but as Mr Bermingham notes (***Spaceflight,*** September 1988, p.367) the Martian week would continually drift in relation to the Terran week. For this reason I differed with the other authors and chose a unique nomenclature for the Martian sols of the week although for mnemonic convenience, it is based on the same roots as the system of names for the Terran days of the week.

French revolutionaries attempted to establish a calendar containing ten-day weeks but Napoleon Bonaparte abandoned it only thirteen years later. The early Soviet government promulgated a calendar incorporating five-day weeks, then replaced it three years later with a calendar of six-day weeks, which in turn had a life of only eight years. So is the seven-day week sacrosanct?

I assert, contrary to Mr Bermingham's closing remark, that a universally accepted Martian calendar is needed now and cannot be left to be debated by future Martian colonists. Over a decade ago, the Viking project team developed a preliminary Martian chronometric system for their own purposes. Unless persuaded otherwise, it is possible the Soviets would invent yet another system for their upcoming unmanned operation on the Martian surface. I foresee a confused state of affairs developing unless we adopt an international standard very soon. It would be more desirable to have the Soviets and Americans using the same system of timekeeping on Mars; indeed, this will be a requirement if the two nations are to cooperate in future Martian ventures. The nomenclature of my Darian calendar is a blend of Eastern and Western influences

Beyond these considerations, the immediate institution of a Martian calendar would serve as an important political and social purpose as a symbol of the human commitment to establish a permanent presence on the world in the coming decades. Although much engineering development remains to be done the process of laying the foundation for a new civilisation should begin now.

THOMAS GANGALE
California, USA

Star Tales

I. Ridpath, Lutterworth Press, PO Box 60, Cambridge, CB1 2NT, 1988, 161pp, £12.95.

The constellations seen in the sky are grouped together not by nature but solely as a result of human imagination. They reflect a desire to impress some order upon the apparent chaos of the night sky. These twinkling points of light are recognised nowadays as glowing balls of gas, a fact unknown to those whose imagination first created the groupings we still accept.

The origin of the constellations is lost in obscurity, though recent evidence indicates that Babylonians and Sumarians may have been the originators. Every night for several thousands of years now, a pageant of Greek mythology has circled overhead. Perseus flies to the rescue of Andromeda, Orion faces the charge of a snorting bull and the ship of the Argonauts sails in search of the golden fleece.

The present book begins with an introduction describing the origin of these stellar groupings and the way they have been depicted in various star maps. This is followed by the main text which takes each constellation in turn and couples a reproduction from the classic star maps of Bode (1801) or Flamsteed (1729) with text describing the origin of each constellation and indicating some of the interesting objects it contains.

No attempt has been made to compare the Greek and Roman constellation figures with those imagined by the Egyptians, Hindu or Chinese

1989 European Space Directory

Sevig Press, 5 Rue Alexandre Cabanel, F-75015 Paris, France, 1989, 548pp, 750FF

This reference work offers nearly 400 in-depth profiles of European and Canadian space companies and institutions. Key information included relates to general management and space contracts, capital, turnover, structure, activities and main space specialisations. The aim is to identify companies and institutions specialising in various space activities or offering particular types of products or services.

Also included are nearly 2,000 names and biographical details of key personnel in the European and Canadian space industries. A further section summarises data on the media directly concerned with space interests, with over 70 newsletters, magazines and periodicals listed.

Last, but not least, the Directory includes a chronology of the major world space events for 1988, an overview of European space programmes on a country-by-country basis, including budgets from 1972 to 1989, and information about the proposed space infrastructure for Europe for the 1990s and beyond.

Apollo: The Greatest Adventure of All Times

R. Kerrod. Prion, Multimedia Books Ltd., 32-34 Gordon House Road, London NW5 1LP. 80pp. 1989. £7.95

In May 1961, President Kennedy urged the American people to seek space supremecy and to land a man on the Moon by the end of the decade. It seemed an impossible task at that time but, on 20th July 1969 and with just 5 months of the decade to run, this incredible goal was achieved.

This book clebrates the 20th anniversary of Neil Armstrong's 'small step' by tracing the beginnings of the Apollo programme through to the gradual build-up of technologies that culminated in the half-dozen lunar landings.

It provides a magnificently-illustrated record of one of the most significant chapters in history.

Beyond the Limits: Flight Enters the Computer Age

P.E. Ceruzzi, The MIT Press, 126 Buckingham Palace Road, London, SW1W 9SA, 1989, 270pp, £11.95 (paperback).

Space flight and aircraft both dominate and utilize leading-edge computer technologies in their design, testing, manufacture, navigation and operation.

The revolution in aerospace technology, which today provides extensive computer simulations for astronauts to practice with throughout their training, has really been going on for at least 40 years. Even though the digital computer, able to perform automatically a variety of arithmetic, memory and control functions, was invented in the 1940s, its origin could be traced back in a direct line to the work of Charles Babbage in the 1830s. These facts are well brought out in this book which shows how the present-day dependence on computers came about and what its consequences may be. Many new facets of the dynamics and evolution of these technologies are also described. Such has been the speed of development that it has been said that even the computers in the Shuttle are very dated by present-day standards.

The application of computers is described in Minuteman, Apollo and in simulation, testing and control. Software ranks for a chapter on its own which not only describes the intricacies of Programming but also reveals, in mentioning that the Shuttle astronauts need to refer to a book of notes that describes minor inconsistencies in the software, how, at best, the production of perfect software is illusive, leading to the conclusion that, in reality, error-free software is probably impossible.

Journey Into Space

B. Murray. W.W. Norton & Co. Ltd., 37 Great Russell Street, London WC1B 3NU. 381pp. 1989. $19.95.

The space journeys undertaken, in only 30 years and ranging from the outer edge of the Earth's atmosphere to the outer reaches of the solar system, provides one of the great sagas of history. It features an intricate mix of promise and frustration, success and failure, scientific advance and political default.

The author is already well-known for his independent views so there is much personal comment as well as a good deal of interesting background information on American space activities. The author feels keenly about the slow-down in the American space programme and does not mince his words, describing the last decade or more as 'the story of a nation lost in space, ... (which) .... doggedly pursued a flawed Shuttle programme to its disastrous collapse.' He points out that, meanwhile, the Soviet space programme surged ahead and that Europe matured to become an independent force in space.

This would not be so bad, he considers, if NASA had been provided with the fillip and wherewithal to advance new projects but he is not confident that this will come about and anticipates that US space achievements will slip yet further, "as victims of a bureaucratic obsession with means rather than ends".

All this adds up to an extremely readable book with a mine of information and an overall result of considerable interest.

For All Mankind

H. Hurt III, Astronomy Now, Intra House, 193 Uxbridge Road, London, W12 9RA, 1988, 352pp, £12.95.

No less than 24 Apollo astronauts went to the Moon between December 1968 and December 1972 in a series of spectacular missions. Then, suddenly, the project was cancelled, leaving a trail of unfulfilled missions. Not one astronaut has returned to the Moon since.

This book presents a dramatic and engrossing account of what, possibly, has been mankind's greatest adventure to date. It is based on extensive research and interviews with astronauts who provide, as realistically as possible, a dramatic account of the sights, sounds, thoughts, hopes and dreams experienced during these epic voyages.

The story begins with pre-launch and goes on to entering Earth orbit, the trans-lunar journey, entering lunar orbit and, finally, descent to the lunar surface itself. The result contains all the ingredients of an exciting adventure story, with failure and success jostling

side by side. Public interest was enormous. When Apollo 11 landed on the Moon on the afternoon of July 20th 1969 (Houston time) and, by 10 p.m. that night, Neil Armstrong was traversing the lunar surface, he was watched by an estimated 600 million people, roughly one-fifth of the world's total population. Over 100 foreign governments, Emperors, Presidents, Prime Ministers and Kings sent warm messages of congratulations.

The flights bequeathed to mankind a huge supply of lunar material, much still unexamined. But the questions posed over the years still remain. Will man return to the Moon once again? Will a Lunar Observatory or Lunar Laboratory, one day, adorn our store of knowledge? The book refers to Sally Ride's report of a fourth initiative - Outpost on the Moon - gloomily adding that, though in many ways the most feasible and promising the greatest long-term rewards, it is the one which has received the least favourable public reaction.

Proceedings of the Nineteenth Lunar and Planetary Science Conference

G. Ryder & V.L. Sharpton, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1989, 757pp, £65.

Notwithstanding the lack of spectacular success from the twin Soviet Phobos Missions, the U.S. Neptune fly-by, the Magellan mission to map the surface of Venus and the Galileo mission to Jupiter have all fostered a sense of optimism that our knowledge of the solar system will soon reach new thresholds. Nowhere was this more apparent than at the 19th Lunar and Planetary Science Conference held in Houston in 1988 which was larger than others of recent years and attracted 770 scientists and more than 360 papers. Topics ranged from plans for an inhabited base on the lunar surface to the geochemical distinctions between the Earth and Moon and tectonic processes in Venus.

Studies of the Moon, many still utilizing results from Apollo flights several decades ago, occupy almost half of the book, with the bulk of the remainder devoted to meteorites, cosmic dust, cometary nuclei and similar primitive materials left over from the formation of the solar system and which, in many cases, caused the impact cratering visible on so many planets and satellites. This preponderance of interest in such objects finds its way also into the articles concerned with the Moon, Mars, and various satellites, though studies of the outer gaseous planets have been omitted, doubtless for the reason that these have already been extensively dealt with elsewhere.

It is extremely interesting to note the shift of emphasis towards probes which, effectively, are devoted to discovering the origins and sequence of events which have led to the solar system as it looks today. Doubtless, future Conferences will, increasingly, feature papers developing our knowledge of minor planets as a further essential ingredient to these studies.

Illustrated History of Man in Space

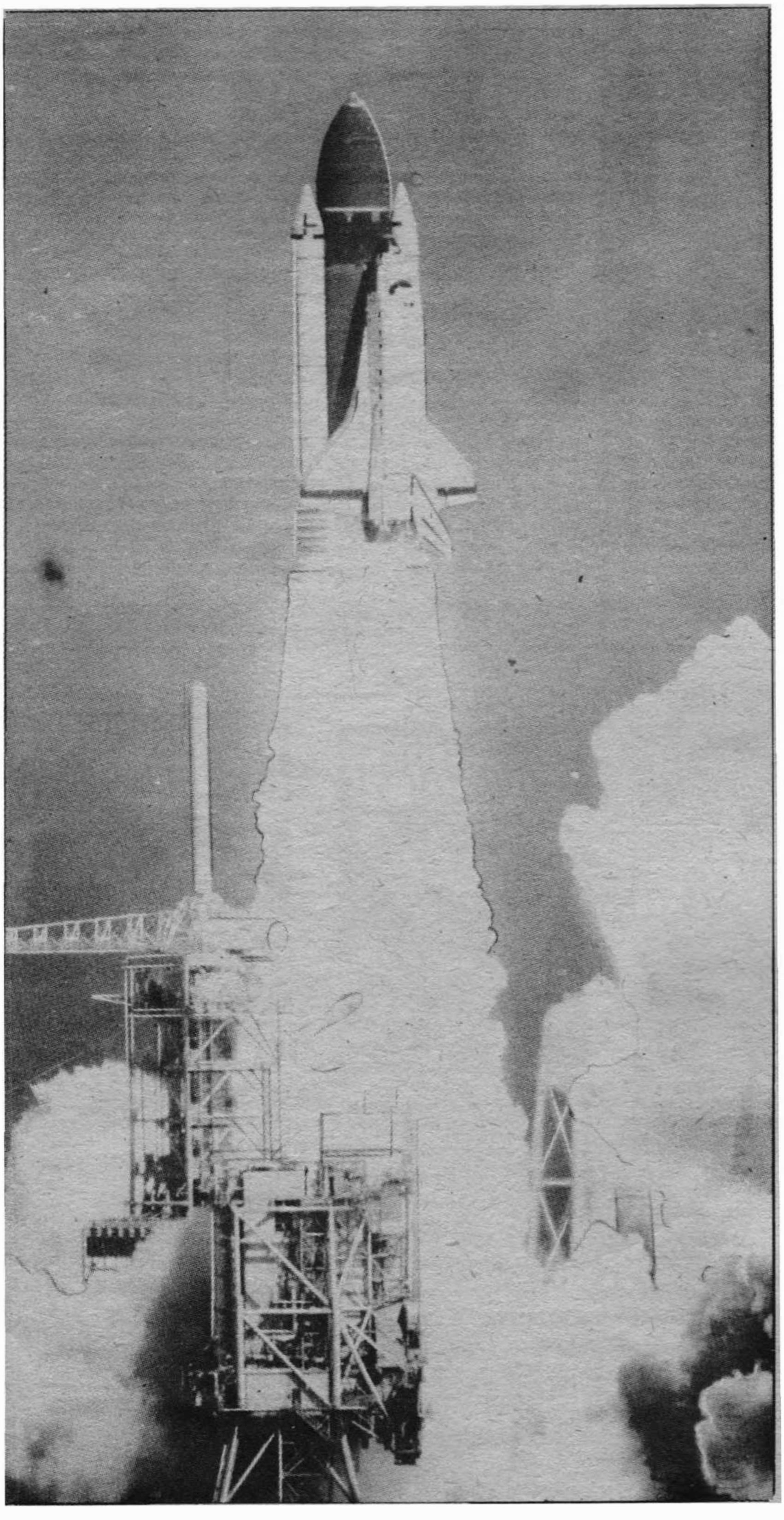
R. Kerrod. Prion, Multimedia Books Ltd., 32-34 Gordon House Road, London NW5 1LP. 216pp. 1989. £14.95

The story of man's struggle to conquer space is both exciting and fascinating and, like all good stories, interwoven with a multitude of plots and sub-plots, heroes and heroines, exhilaration and tragedy.

This book traces the story of man's advance into space from the relatively short missions of Mercury and Vostok to the marathons of Skylab, Salyut and Mir.

It is a book which encapsulates many of those exciting moments with the aid of a most readable text and a wealth of superb illustrations.

Shuttle Gets Galileo Underway



Atlantis blasts off from Pad 39-B at the Kennedy Space center· NASA

THE long awaited Galileo probe finally blasted off onboard the Space Shuttle Atlantis on October 18. The mission was originally scheduled for October 12 but was delayed due to a problem with a main engine controller and bad weather at the Cape. The probe was successfully deployed from Atlantis about six hours 21 minutes into the mission. Crew members, Commander Don Williams, Pilot Mike McCulley and Mission Specialists Shannon Lucid, Ellen Baker and Franklin Chang-Diaz, returned to Earth on October 23 after almost five days in orbit.

Engine Problem Delays Launch

After a relatively smooth launch preparation period the countdown clocks began ticking in readiness for an October 12 launch at 08:00 EDT on October 9. Later that day the STS-34 flight crew arrived in their T-38 jets.

Meanwhile, on October 10, in Washington, a federal judge refused to halt the flight, as requested by protesters objecting to the use of RTGs on Galileo. With the legal barriers down it was technical problems that were to stop the launch. The same day as the verdict was delivered, it emerged that technicians had noticed a 'glitch' during testing of a main engine controller.

Each Space Shuttle Main Engine has a controller containing two digital computers and the associated electronics to control all main engine components and operations. The two computers are referred to as channels A and B. Normally channel A electronics are in control. If channel A fails, channel B will assume control. But if channel B subsequently fails, the engine will be shut down. The fault was detected in the back-up channel B. Rocketdyne and NASA engineers repeatedly retested the engine but saw no reoccurrence of the problem.

Shuttle managers feared a repeat of the problem during launch could cause the main engine to shutdown. The ever cautious officials decided to replace the suspect controller. NASA believed there was a fifty-fifty chance of completing the work in time for a launch on October 17. The countdown was held at the T-19 hour point during the controller changeout.

Out at the pad workers immediately began work to replace the controller. The orbiter's aft compartment was opened and special work platforms were set up to allow removal of the main engine heat shields and give

access to the controller. The faulty controller belonged to Main Engine No.2.

During the evening of October 12 the faulty controller was removed and a spare put in its place. Engineers completed work to make the two dozen connections between the engine and the new controller the next morning.

The controller was retested and given a clean bill of health.

Shuttle managers decided to attempt a launch on October 17. The launch window for that day extended from 12:57 to 13:23 EDT.

"The changeout process was accomplished with great efficiency by a dedicated team," said Robert Crippen, the then Deputy Director, National Space Transportation System Operations.

The same evening the STS-34 crew flew back to KSC from Houston where they had returned during the delay for additional simulation runs.

The countdown resumed at 00:01 on October 16.

Weather Halts Launch

Preparations for the launch on October 17 continued to run smoothly. The External Tank was filled with its load of Liquid Hydrogen and Liquid Oxygen during the early hours of the morning on October 17.

By 11:00 EDT the crew were strapped in their seats aboard the orbiter and the crew hatch was closed.

The weather forecast was good, the Air Force was predicting an 80 per cent chance of acceptable weather. But the 20 per cent chance of a scrub was to win the day.

From the press site, looking towards Pad B, about 3.9 miles away, blue skies dominated the scene. However anyone turning around and looking west towards the Shuttle Landing Facility (SLF) saw a different picture. Almost stationary black storm clouds hung over the landing strip where the Shuttle would land if an abort occurred during the early stages of the mission.

The countdown had reached the 40 minute built-in hold at T-9 minutes without major incident. But the countdown did not resume on schedule because meteorologists could not give a 'go' for launch.

A frustrated Don Williams, lying on his back in the left hand seat in the cockpit, gazed out of his windows and tried to offer some help: "All I see is blue skies!" he radioed.

Launch Director Bob Sieck and his team decided to take the countdown to the T-5 minute point. But the weather over the SLF refused to clear. Then, as if to add insult to injury, the Trans-Atlantic Abort Site at Ben Guerir, Morocco, reported unacceptable weather for a landing there. The two alternative TAL sites were also reporting bad weather.

Although Ben Guerir later reported the weather had improved, the situation at KSC grew worse. There was rain at the approach end of the SLF and lightning had been detected within ten miles of the runway.

With the launch window ebbing away, Bob Sieck, radioed the crew and told them he was going to call it a day.

The crew access arm was swung back into position and a disappointed crew returned to their quarters.

After assessing the situation Shuttle managers decided to reset the launch for the next day. The forecast for October 18 was not good. There was a 40 per cent chance of weather violating the launch requirements and thunderstorms and rain showers were predicted to be in the KSC vicinity.

Launch Day

The crew woken at about 07:30 on October 18 and, for the second time in as many days, they made their way to the launch pad.

Few expected to see a launch that day. The weather was looking worse than the previous day and there were several rain showers during the morning. It was not until the T-9 minute hold was coming to an end that KSC weather officers finally gave a go for

LAUNCH PREPARATIONS

Atlantis was towed to the Orbiter Processing Facility (OPF) Bay 2 on May 16 after its return to the Kennedy Space Center (KSC) following the STS-30 mission. The three main engines were removed the last week of May and taken to the main engine shop in the Vehicle Assembly Building (VAB) for the replacement of several components including the high pressure oxidizer turbopumps. The engines were reinstalled the first week of July, while Atlantis was in the OPF. Engine 2027 in the No.1 position, engine 2030 in the No.2 position and engine 2029 in the No.3 position. All three engines were used on STS-27 and STS-30.

The orbiter's two Orbital Maneuvering System (OMS) pods were removed for repairs in the Hypergolic Maintenance Facility.

A cooling system for the Radioisotope Thermoelectric Generators (RTGs) was installed onboard Atlantis. A mixture of alcohol and water flows in the special cooling system to lower the RTG case temperature. The cooling lines were mounted on the port side of the orbiter from the aft compartment to a control panel in Bay 4.

Special instrumentation, called "flutter buffet", was installed on the vertical tail and right and left outboard elevons. Ten accelerometers were added to the vertical tail and one on each of the elevons. These instruments are designed to measure in-flight loads on the orbiter's structure. Atlantis is the only vehicle that will be equipped with this instrumentation. Bob Crippen told a prelaunch press conference the instrumentation will gather data to assure engineers that the Shuttle could be flown at a little higher dynamic pressure than present safety rules allow.

A total of 34 modifications were made to Atlantis before STS-34.

Stacking of the Solid Rocket Boosters (SRBs) for STS-34 began in the VAB on June 15. The stacking operations were completed by July 22 and the External Tank (ET) was mated to the two boosters on July 30.

The Galileo descent probe arrived at KSC's Spacecraft Assembly and Encapsulation Facility 2 (SAEF-2) on April 17, followed by the main spacecraft on May 16. While at SAEF-2 the spacecraft and probe were mated, then tested together to verify critical connections. Galileo was delivered to the Vertical Processing Facility (VPF) on August 1. The Inertial Upper Stage (IUS) arrived at the VPF on July 30. Galileo and the IUS booster were joined together on August 3 and an all integrated test was performed during the second week of August.

The Shuttle Solar Backscatter Ultraviolet (SSBUV) experiment, contained in two Get Away Special (GAS) canisters, was mounted on a special GAS beam in Atlantis' payload bay on July 24.

Atlantis was transferred from the OPF to the VAB on August 21, where it was mated to the ET and SRBs.

The assembled Shuttle was rolled out of the VAB atop Mobile Launch Platform-1 for the 4.2 mile trip to Pad 39-B on August 29. Galileo and its IUS upper stage had been transferred from the VPF to Pad 39-B on August 25. The spacecraft was installed in Atlantis' payload bay on August 30.

A Terminal Countdown Demonstration Test, with the STS-34 crew participating was carried out on September 14 and 15.

KSC Shuttle managers were prepared to roll Atlantis back to the VAB in mid-September when it seemed Hurricane Hugo might threaten the Cape Canaveral area. The payload bay doors were closed and platforms retracted. A crawler transporter stood by at the gates to Pad 39-B in case a roll back became necessary. In the event Hurricane Hugo passed more than 200 miles east of Cape Canaveral, with KSC experiencing only minor effects.

launch. However, soon after the count resumed, the weather at Ben Guerir had become unacceptable, prompting a switch to one of the alternative runways at Zaragoza in Spain. The countdown was halted at T-5 minutes to give the crew time to reset Atlantis' computers for the new landing site. The clock resumed at 12:48:40 EDT.

The remainder of the countdown was accomplished without incident.

The three main engines began their ignition sequence at T-6.6 seconds and were followed by SRB ignition and lift-off at 12:53:40 EDT. Atlantis rose from the pad on a pillar of flame, brighter than the Sun. Seconds after clearing the tower, the Shuttle performed a 120 degree roll manoeuvre, placing it on the correct trajectory for an orbital inclination of 34.30 degrees - the first time this inclination has been used.

The SRB separation occurred at T+2 min 5 sec and was clearly visible to observers on the ground. The two boosters splashed down in the Atlantic about 295 seconds later, ten miles from the SRB recovery ships. They were returned to Cape Canaveral the next day. Initial examinations showed them to be in good condition. The STS-34 boosters included two segments that had flown on STS-26 and one segment that had been fired five times. It was the first time SRB segments flown since the Challenger accident have been reused.

As the boosters drifted towards the ocean, Atlantis continued towards orbit. The three main engines completed their work and were shutdown at 8 min 35 sec after blast off.

Following ET separation at about T+8 min 51 sec, Atlantis was manoeuvred so the crew could photograph the departing ET as part of an evaluation of the tank's thermal protection system.

Atlantis employed the Direct Ascent to Orbit procedure requiring just a single OMS burn to circularise the orbit. The burn occurred 42 minutes into the flight and lasted 2 minutes 15 seconds.

NASA was relieved to get Atlantis in orbit on October 18 because Air Force weather forecasters were predicting a cold front would arrive later that day bringing storms with it. Within hours of Atlantis leaving the launch pad the KSC area was engulfed in a tremendous thunderstorm. The weather the following days was equally overcast.

The STS-34 crew leave the Operations and Checkout Building on their way to launch pad 39B *NASA*

Shuttle Solar Backscatter Ultraviolet Instrument

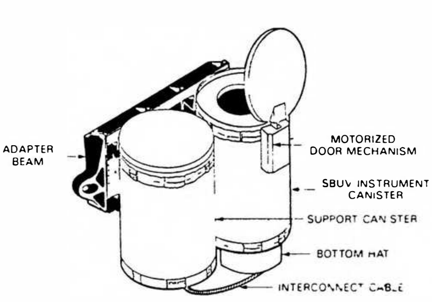
The Shuttle Solar Backscatter Ultraviolet (SSBUV) instrument was developed by NASA to calibrate similar ozone measuring space-based instruments on the National Oceanic and Atmospheric Administration's TIROS satellites (NOAA-9 and -11).

The SSBUV will help scientists solve the problem of data reliability caused by calibration drift of solar backscatter ultraviolet (SBUV) instruments on orbiting spacecraft. The SSBUV uses the Space Shuttle's orbital flight path to assess instrument performance by directly comparing data from identical instruments aboard the TIROS spacecraft, as the Shuttle and the satellite pass over the same Earth location within a 1-hour window. These orbital coincidences can occur 17 times per day.

The SBUV measures the height distribution of ozone in the upper atmosphere. It does this by measuring incident solar ultraviolet radiation backscattered from the Earth's atmosphere. The SBUV measures these parameters in 12 discrete wavelength channels in the ultraviolet. Because ozone absorbs in the ultraviolet, an ozone measurement can be derived from the ratio of backscatter radiation at different wavelengths, providing an index of the vertical distribution of ozone in the atmosphere.

Global concern over the depletion of the ozone layer has sparked increased emphasis on developing and improving ozone measurement methods and instruments. Accurate, reliable measurements from

SSBUV CANISTERS



space are critical to the detection of ozone trends, for assessing the potential effects and development of corrective measures.

The SSBUV instrument and its dedicated electronics, power, data and command systems are mounted in the Shuttle's payload bay in two Get Away Special canisters, an instrument canister and a support canister. Together, they weigh approximately 1200lb. The instrument canister holds the SSBUV, its specially designed aspect sensors and in-flight calibration system. A motorized door assembly opens the canister to allow the SSBUV to view the Sun and Earth and closes dunng the in-flight calibration sequence.

The support canister contains the power system, data storage and command decoders. The dedicated power system can operate the SSBUV for a total of approximately 40 hours.

Growth Hormone Concentrations and Distribution in Plants

The Growth Hormone Concentration and Distribution in Plants (GHCD) experiment is designed to determine the effects of microgravity on the concentration, turnover properties, and behaviour of the plant growth hormone, Auxin, in corn shoot tissue (Zea Mays).

Mounted in foam blocks inside two standard middeck lockers, the equipment consists of four plant canisters, two gaseous nitrogen freezers and two temperature recorders

A total of 226 specimens (Zea Mays seeds) were 'planted' in special filter paper, paper-Teflon tube holders less than 56 hours prior to flight. The seeds remained in total darkness throughout the mission.

The GHCD lockers were installed in the orbiter middeck within the last 14 hours before launch.

On Flight Day Five two of the plant canisters were placed into the gaseous nitrogen freezers to arrest the plant growth and preserve the specimens. The payload will be restowed in the lockers for the remainder of the mission

The experiment was returned to investigators soon after landing

Day One: October 18, 1989

Following the OMS burn the crew began to prepare for their stay in orbit. This work included opening the payload bay doors, stowing the Mission Specialists seats and unpacking cabin equipment.

Soon after entering orbit the crew were alerted by an alarm indicating the Orbiter's Flash Evaporator System (FES) had switched from its normal low cooling mode to a high load subsystem. The FES provides cooling for the Shuttle systems during launch and reentry when the payload bay door radiators cannot be used. NASA believes the FES was overloaded by excess heat from the Galileo's RTGs.

The crew were alerted to the presence of Super-Typhoon Elsie in the Sea of Japan. Mission Control felt it would make a good subject for some IMAX photography. A satellite image of the typhoon was transmitted to the crew via the Text and Graphics System (TAGS) to help them identify it.

The astronauts began preparations for the deployment of Galileo with a full checkout of the probe's IUS booster. The exact position of the Shuttle was transmitted to the IUS booster's guidance system At T+ 5 hrs 42 min, the crew reported they had raised the IUS tilt table to 29 degrees

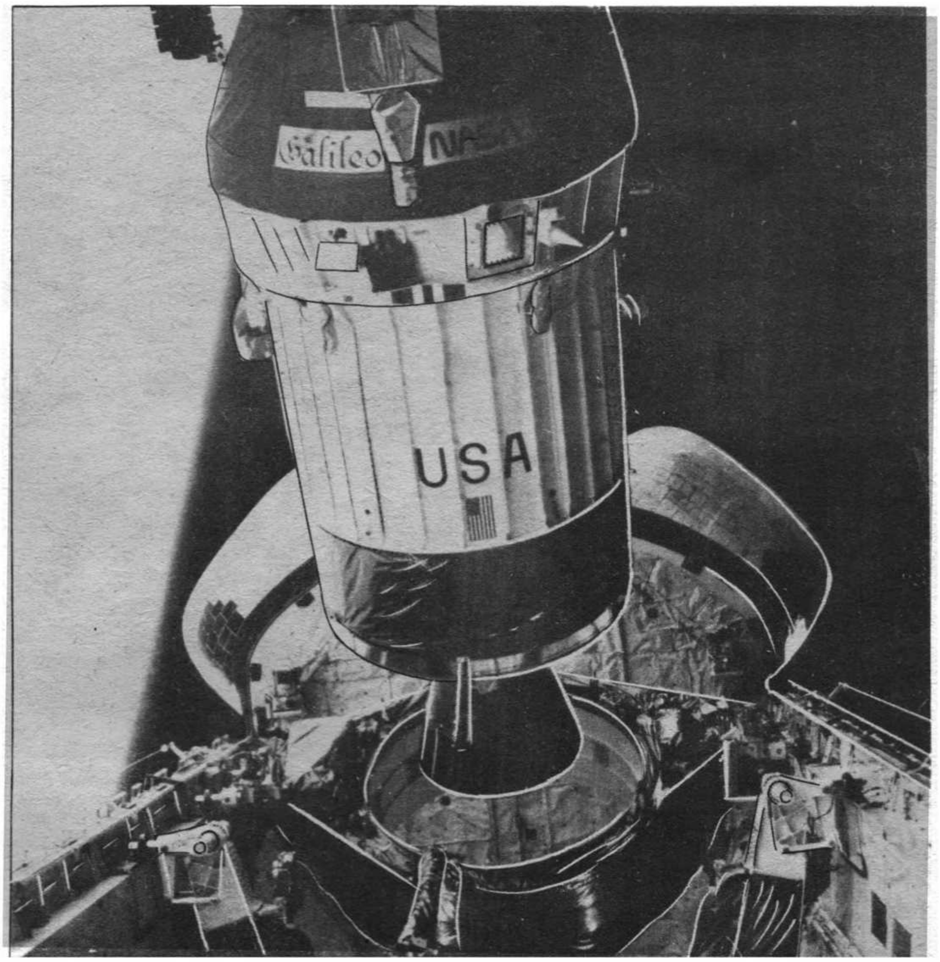
Just under six hours into the flight the crew were given the go-ahead to deploy the probe. Umbilicals between the orbiter and the Galileo/IUS were severed and the tilt table was raised to the deployment position of 58 degrees.

As Atlantis passed over Brownville, Texas, six hours, 21 minutes and 23 seconds into the mission, Shannon Lucid flipped the switches on the orbiter's flight deck to release the IUS from its tilt table. Compressed springs - no larger than a fist - provided the force to jettison Galileo and its booster from the orbiter payload bay at a velocity of about 0.4 feet per second.

"Galileo is on its way to another world," a triumphant Commander Williams radioed Mission Control.

Atlantis' Reaction Control System thrusters were fired to gradually increase the distance between the orbiter and IUS/Galileo. An OMS burn of 16 seconds further separated the two spacecraft and changed Atlantis' orbit to 161 x 178 nm. In the payload bay the tilt table had been lowered to its storage position of minus six degrees.

After observing the departing IUS/ Galileo combination, the crew turned Atlantis' underside towards the booster to protect the orbiter's windows from the exhaust of the IUS first stage. The Atlantis crew were eager to be kept up-to-date with Galileo's progress and asked Mission Control to keep them fully informed.



The Galileo Jupiter probe at the moment of deployment from the Space Shuttle Atlantis *NASA*

The IUS first stage motor ignited an hour after deploy and burnt for 149 seconds. Less than a minute after the first stage burnt out it separated from the IUS. The second stage ignited about 150 seconds later and fired for about 105 seconds.

About an hour and ten minutes after deploy the IUS second stage fired its thrusters for about 40 minutes, spinning Galileo to 2.8 revolutions per minute. Galileo separated from the IUS second stage at 21:05 EDT. The second stage continued to fire its thrusters for approximately 30 minutes to manoeuvre the stage away from Galileo.

Ground controllers reported the IUS had performed "flawlessly".

At about 21:45 EDT the crew began a well earned sleep period.

Day Two: October 19, 1989

The STS-34 crew were woken at 07:53 EDT with a tribute to Commander Williams and Pilot McCulley consisting of "Hail Purdue," "Revellie" and "Anchors Aweigh." Both astronauts are graduates of Purdue University and are officers in the US Navy.

The teleprinter was used to send the crew congratulations on a highly successful first day in orbit. NASA Administrator Truly complemented the crew "on a job well done" The IUS control center at Onizuka Air Force Base told the crew they enjoyed working with them on yet another precise IUS deploy. They wished the crew continued success during their mission and a safe return.

The IMAX camera was used to obtain 72 mm photography of various areas on the Earth's surface. The crew had been advised Mount Etna was smoking and were asked to photograph the plume, if visible from orbit. The crew reported good photography of oil fields in west Texas. But cloud cover obscured the Grand Canyon and haze hampered photography of volcanos in Indonesia. As Atlantis passed over the Sea of Japan the crew were able to photograph Super-Typhoon Elsie using payload bay cameras and the IMAX system. The IMAX photography will be incorporated into "Blue Planet," a presentation for the Smithsonian National Air and Space Museum. STS-34 is the fifth flight of the IMAX camera.

Franklin Chang-Diaz and Ellen

Baker performed a medical experiment, involving photographing and videotaping the veins and arteries in the retinal wall of Baker's eye ball. The experiment's investigators believe that detailed measurements of these vessels might give clues about a possible relationship between cranial pressure and space motion sickness.

The crew were concerned about the lack of results from the student experiment designed to measure zero gravity growth of ice crystals. Commander Williams transmitted video of the experiment to the ground to see if investigators could determine why the experiment was not working.

Day Three: October 20, 1989

Capcom Tammy Jernigan woke the STS-34 crew with a medley of songs from the Mission Specialists university days: For Shannon Lucid, "Boomer Sooner" from the University of Oklahoma; for Franklin Chang-Diaz, "UConn Huskie" from the University of Connecticut; and for Ellen Baker, "Victory March" from the State University of New York at Buffalo.

One of the first tasks on the crew's third day in orbit was to remedy a malfunctioning valve on one of Atlantis' cryogenic oxygen tanks. The valve had failed to close properly the previous night just as the crew entered their sleep period. The astronauts had placed the tank in a safe condition overnight, while mission control analysed the problem from the ground. However, the problem quickly resolved itself when McCulley tried and succeeded in closing the valve. Controllers continued to monitor the valve throughout the remainder of the mission.

The crew reactivated the student ice crystal experiment. The experiment had failed to produce crystals on Flight Day Two because the supercooled water collected and formed ice slag on the cooling plate. The crew switched the experiment off, allowing the ice slag to thaw, then added more water. The procedure was successful. An hour after reactivation, Shannon Lucid reported the formation of ice crystals and used the onboard camcorder, fitted with a fibre optics attachment to transmit pictures to the experiment's student investigator Tracy Peters.

STS-34 was the second time Atlantis carried a commercially available video camcorder. The camera was first used on STS-30 to demonstrate the feasibility of using this type of small lightweight camera in space. STS-30 was not the first space mission to carry a commercially available video camera, as previosuly thought. Syrian cosmonaut Mohammed Faris used a camcorder during the Soyuz TM-3 mission in July 1987.

Mission Specialist Ellen Baker, a medical doctor, conducts a medical examination on Franklin Chang-Diaz. Baker is monitoring Chang-Diaz's blood flow *NASA*

The TAGS machine had been working well during the mission. However, when a large number of sheets were transmitted, the paper tended to fold back on itself in the receiving tray and occasionally cause a paper jam. The camcorder and fibre optic attachment was used to record the paper stacking in the TAGS tray to see if any improvement could be made. During the flight the TAGS machine was used to send the crew a daily crossword to fill their spare time.

The crew obtained good data for the Mesoscale Lightning Experiment over Africa and Australia and on two successive orbits were able to photograph Aurora Australias, the Southern Lights.

Forecasters were predicting rain and strong winds at Edwards Air Force Base for landing, scheduled for about 15:30 EDT on October 23. As a standard procedure in these circumstances, the crew were instructed to look for measures to conserve electricity in case the mission had to be extended.

The IMAX camera was used during Day Three to film the straits of Gibraltar, Greece and its many islands, the island of Crete, the Aswan Dam, the Nile River and its delta, and the deserts of Saudi Arabia, including the many irrigation circles visible from space. The crew were also advised of an opportunity to photograph the planet Jupiter, the destination of the Galileo probe deployed earlier in the mission.

Day Four: October 21, 1989

"Bohemian Rhapsody" by the rock band Queen greeted the STS-34 crew at 07:24 EDT at the beginning of their fourth day in space.

In their regular morning mail, transmitted via TAGS, the crew were given a list of targets for Earth observation photography. (See ***Spaceflight,*** June 1989, p.212 for further details of Shuttle Earth photography.) The targets included a developing tropical storm near Bermuda, a Saharan dust storm and damage to barrier islands on the US east cost after Hurricane Hugo.

During the day the crew worked on the Mesoscale Lightning Experiment, the Polymer Morphology experiment, the IMAX camera and the Shuttle Solar Backscatter Ultraviolet instruments.

At 18:15 EDT Costa Rican President Dr Oscar Arias Sanchez talked with Mission Specialist Franklin Chang-Diaz and the rest of the STS-34 crew via a special telephone link-up between Atlantis and San Jose, Costa Rica. Chang-Diaz, a native of Costa Rica, explained the mission's objectives in Spanish to viewers on the ground. Arias congratulated the crew on its successful mission so far and thanked Chang-Diaz for being an example to young Costa Ricans of what they can achieve.

Chang-Diaz closed the SSBUV hatch around 19:45 EDT, after the instrument package took its last solar recording of the mission at the beginning of orbit 53. Commander Williams then instructed the SSBUV to begin calibrating its data, a process that took about one hour. The experiment was deactivated shortly afterwards.

During the day Shuttle managers decided to bring Atlantis home at least one orbit early due to the predicted bad weather at Edwards. The crew entered its sleep period one and a half hours earlier than planned to gradually adjust sleep schedules to accommodate the earlier reentry and landing.

Day Five: October 22, 1989

The STS-34 crew were woken with John Fogerty singing 'Centerfield' for all the "sports fans on board," according to the explanation transmitted to the crew.

Much of the work on Day Five was in preparation for the return to Earth. Williams and McCulley carried out the Flight Control Systems check-out and a hot fire test of the Reaction Control System. The mid-deck equipment was stowed.

The MLE gathered video of lightning over the east coast of Australia and central Africa, as well as south of Java in Indonesia. The crew used the camcorder to record unexpected lightning over Rio de Janeiro.

Shannon Lucid and Ellen Baker wrapped up the Growth Hormone Concentrations and distribution in Plants (GHDC) experiment by freezing samples of corn seedlings grown in weightless conditions during the mission.

The crew used the 70 mm format IMAX camera to record some film of the Shuttle interior. Mike McCulley then stowed the camera for reentry.

The TAGS system was also deactivated. In all the crew received 522 pages during the mission: 364 pages as part of the test of the system, 148 pages of operational information for the crew and ten pages of blank lead paper.

During the day it was decided to end the mission two orbits early. NASA weather forecasters were predicting satisfactory weather early on landing day, but a steady deterioration as the day progressed.

On their last day in space the crew received a final 'goodnight' from Mission Control at 20:51 EDT. As the crew entered their sleep period the PM experiment was processing its final samples.

Day Six: October 23, 1989

The crew completed the preparations for the return to earth. The PM experiments was deactivated and stowed and the Mission Specialist seats were reinstalled on the aft flight deck and the middeck areas.

The STS-34 crew pose near their spacecraft after landing. (Left to Right) Mike McCulley, Don Williams, Ellen Baker, Franklin Chang-Diaz and Shannon Lucid. *NASA*

The crew donned their pressure suits and the payload bay doors were closed. The orbiter was turned so its engines faced the direction of travel. About an hour before landing the OMS engines were fired for 2 min 48 sec to begin the reentry. The orbiter began to enter the upper layers of the atmosphere at about 12:02 EDT.

Commander Williams took control of Atlantis at Mach .95 and flew the remaining subsonic landing approach manually. Atlantis touched down on Runway 23 at Edwards at 12:32 EDT, after a mission of four days, 23 hours and 41 minutes.

Bill Lenoir, NASA Associate Administrator for Space Flight, said: "The vehicle looks amazingly clean. With a quick inspection, we did not see any significant tile damage."

The initial tile inspection revealed some nicks on tiles but no tiles were missing. Overall, about 25 'dings' were reported in the orbiter's lower surface. Tiles on the upper surface were reported in good shape. The reinforced carbon-carbon chin panel also was reported in good shape and will not have to be removed prior to Atlantis' next flight in February.

Normal scuffing was observed on Atlantis' tyres and no damage was reported on the brakes.

As the crew left the orbiter and were welcomed by members of NASA's senior management, controllers at the Jet Propulsion Laboratory reported Galileo was in excellent condition and already three-quarters of a million miles into its six year trek to Jupiter.

STS-34 At a Glance

ORBITER: Atlantis OV-104
LAUNCHED: 17:53:40-0766 BST, October 12, 1989
LAUNCH SITE: MLP-1, Pad 39B, Kennedy Space Center, USA
LANDED: 17:32 BST, October 23, 1989
LANDING SITE: Runway 23 , Edwards Air Force Base, USA
APOGEE: 177 nm
PERIGEE: 161 nm
INCLINATION: 34.3 degrees
DURATION: 4 days, 23 hrs, 41 mins
COMMANDER: Donald Williams
PILOT: Michael McCulley
MISSION SPECIALIST 1: Shannon Lucid
MISSION SPECIALIST 2: Franklin Chang-Diaz (EV-1)
MISSION SPECIALIST 3: Ellen Baker (EV-2)
PRIMARY PAYLOAD: Galileo/IUS-19
SECONDARY PAYLOADS:
- Shuttle Solar Backscatter Ultraviolet (SSBUV)
- Growth Hormone Concentration and Distribution in Plants (GHCD)
- Mesoscale Lightning Experiments (MLE-03)
- Polymer Morphology (PM)
- Sensor Technology Experiment (STE & IMAX-02)
- SE 82-15 (Student Experiment)
- AMOS-03 (Air Force Mani Optical Site Tests)